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United States Patent [19]

Kasai et al.

[11] **Patent Number: 6,118,429**

[45] **Date of Patent: Sep. 12, 2000**

[54] **LIQUID CRYSTAL DISPLAY SYSTEM CAPABLE OF REDUCING AND ENLARGING RESOLUTION OF INPUT DISPLAY DATA**

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[73] Assignee: **Hitachi, Ltd.**, Tokyo, Japan

[21] Appl. No.: **08/315,714**

[22] Filed: **Sep. 30, 1994**

[30] **Foreign Application Priority Data**

Sep. 30, 1993	[JP]	Japan	5-245205
Oct. 7, 1993	[JP]	Japan	5-251363

[51] **Int. Cl.**^{7} **G09G 3/18**

[52] **U.S. Cl.** **345/132**; 345/138; 345/136; 345/127; 345/87; 348/458

[58] **Field of Search** 348/392, 424, 348/448, 458; 345/132, 202, 129, 130, 127, 138, 136, 1–3, 87, 88, 99, 98

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Primary Examiner—Lun-Yi Lao
Attorney, Agent, or Firm—Antonelli, Terry, Stout & Kraus, LLP

[57] **ABSTRACT**

A liquid crystal display system which can accept display data having a resolution different from that of a screen for the liquid crystal display and display the display data. For example, a CPU outputs display data of 1120×780 dots and a liquid crystal panel has a 1024×768-dot resolution which is smaller than the display data resolution. The display screen of the liquid crystal panel comprises a linear arrangement of pixels. A data conversion section generates display data for a new horizontal or vertical line based on display data for two horizontal or vertical lines contiguous to each other and repeats replacement of display data of the two lines with the display data of the one line for reducing the number of horizontal lines of one screen and the number of dots of one line so as to match the resolution of the display data output by the CPU with the liquid crystal display. In contrast, if the resolution of the display data is smaller than the screen resolution of the liquid crystal panel, the data conversion section inserts the display data of the new one horizontal or vertical line between the two contiguous lines for enlarging the resolution of the display data.

29 Claims, 27 Drawing Sheets

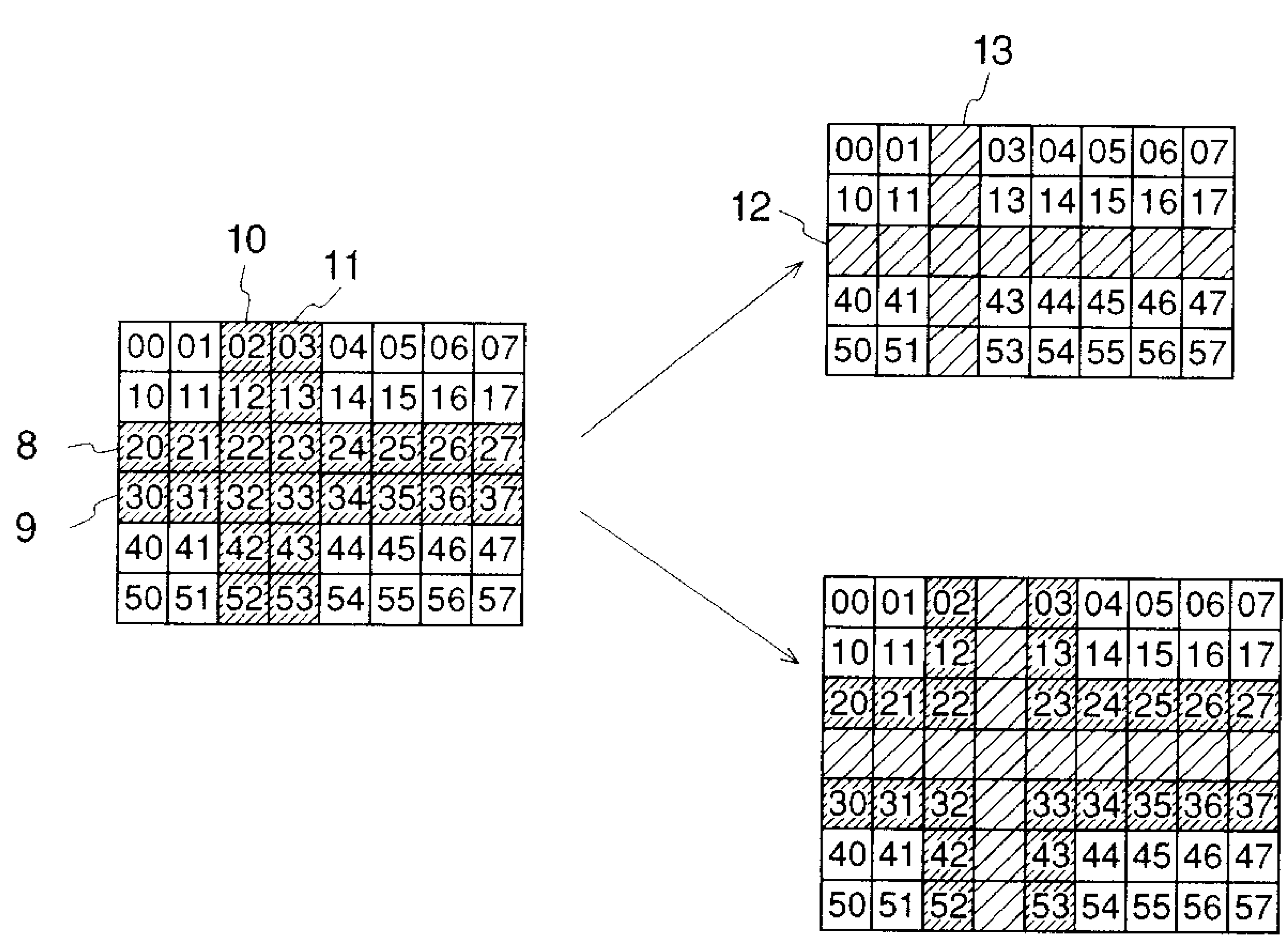


FIG.1

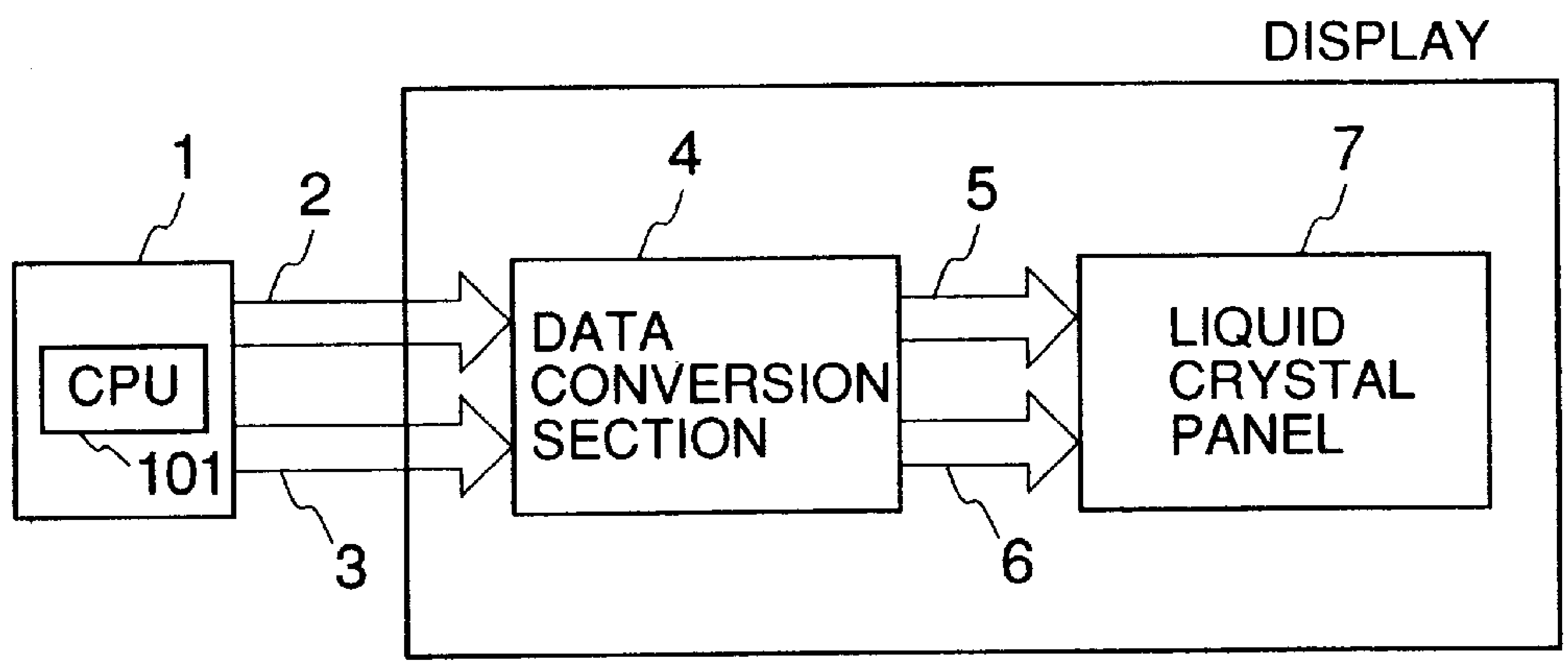

DISPLAY
1
2
4
5
7
CPU
101
DATA
CONVERSION
SECTION
LIQUID
CRYSTAL
PANEL
3
6

FIG.2

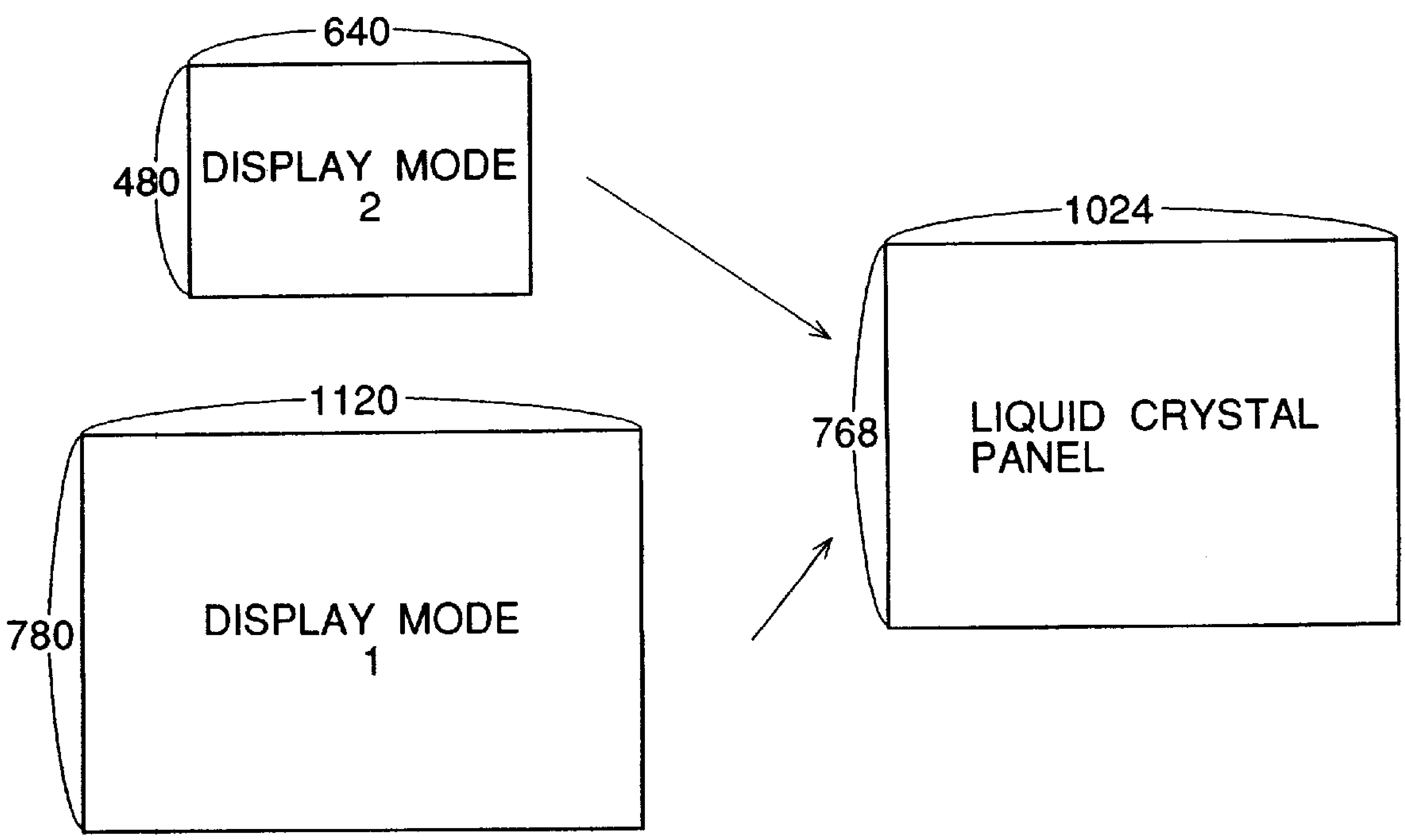

640
480
DISPLAY MODE
2
1024
768
LIQUID CRYSTAL
PANEL
1120
780
DISPLAY MODE
1

FIG.3

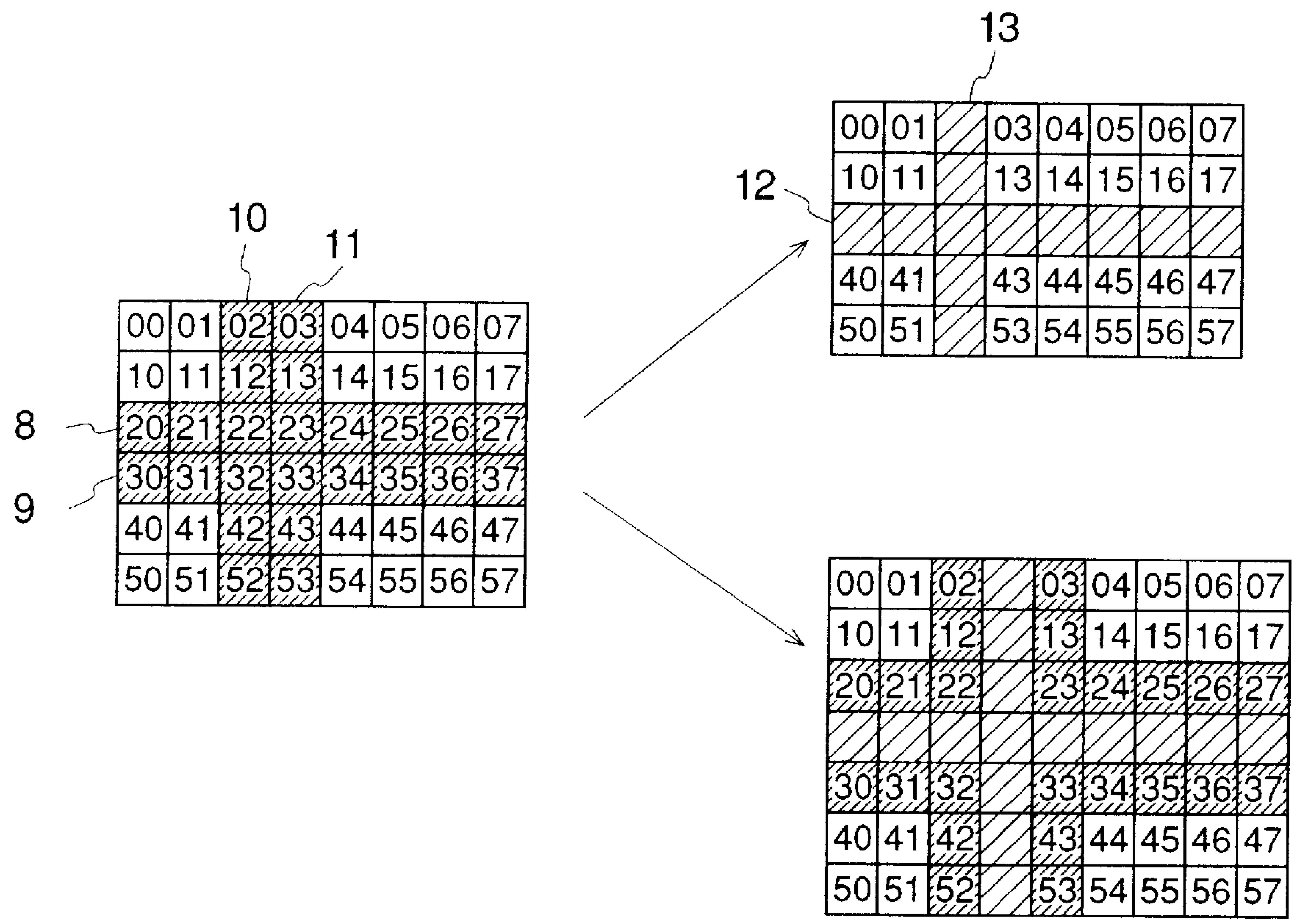

10
11
8
9
00 01 02 03 04 05 06 07
10 11 12 13 14 15 16 17
20 21 22 23 24 25 26 27
30 31 32 33 34 35 36 37
40 41 42 43 44 45 46 47
50 51 52 53 54 55 56 57
13
12
00 01 03 04 05 06 07
10 11 13 14 15 16 17
40 41 43 44 45 46 47
50 51 53 54 55 56 57
00 01 02 03 04 05 06 07
10 11 12 13 14 15 16 17
20 21 22 23 24 25 26 27
30 31 32 33 34 35 36 37
40 41 42 43 44 45 46 47
50 51 52 53 54 55 56 57

FIG.4

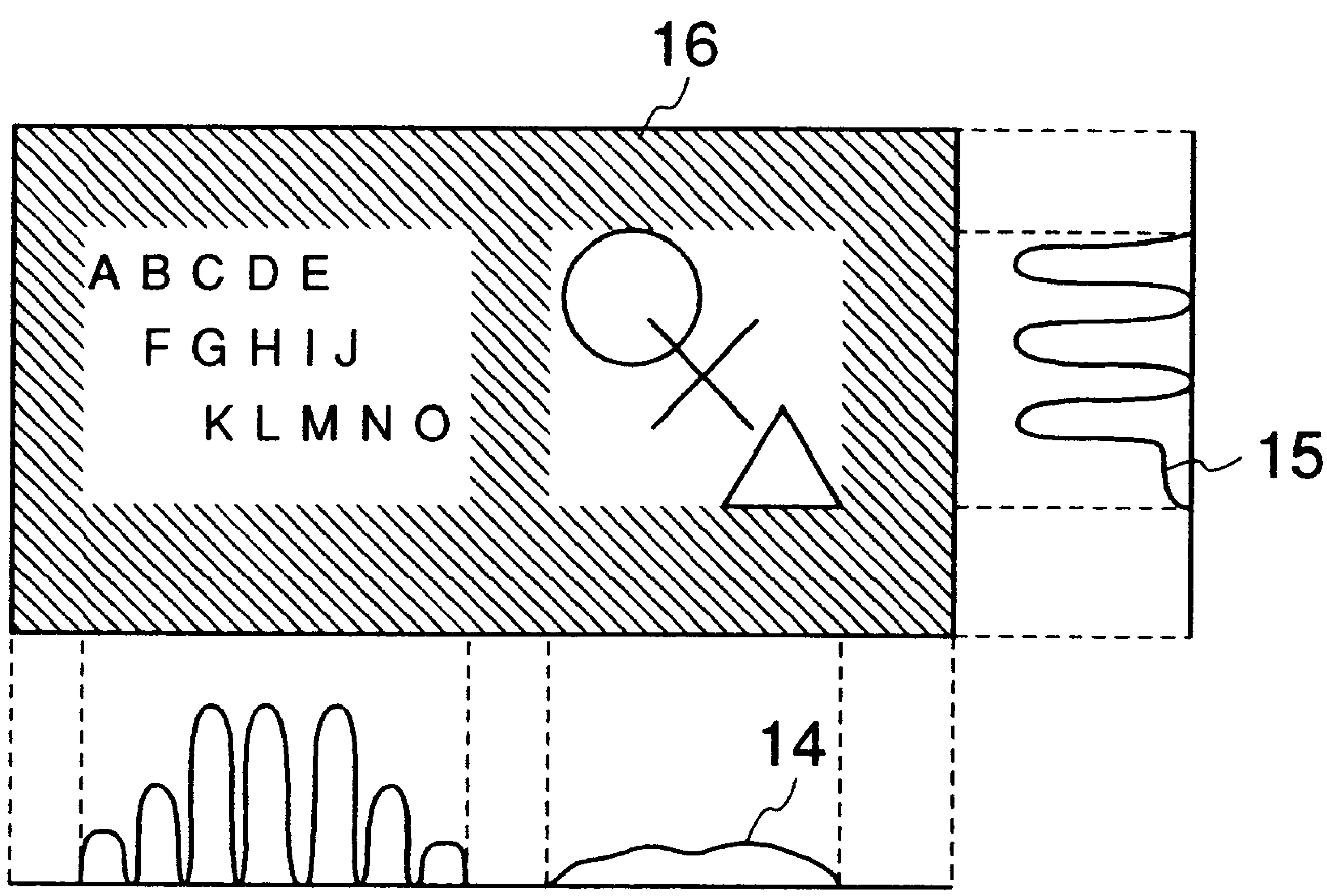


FIG.5A

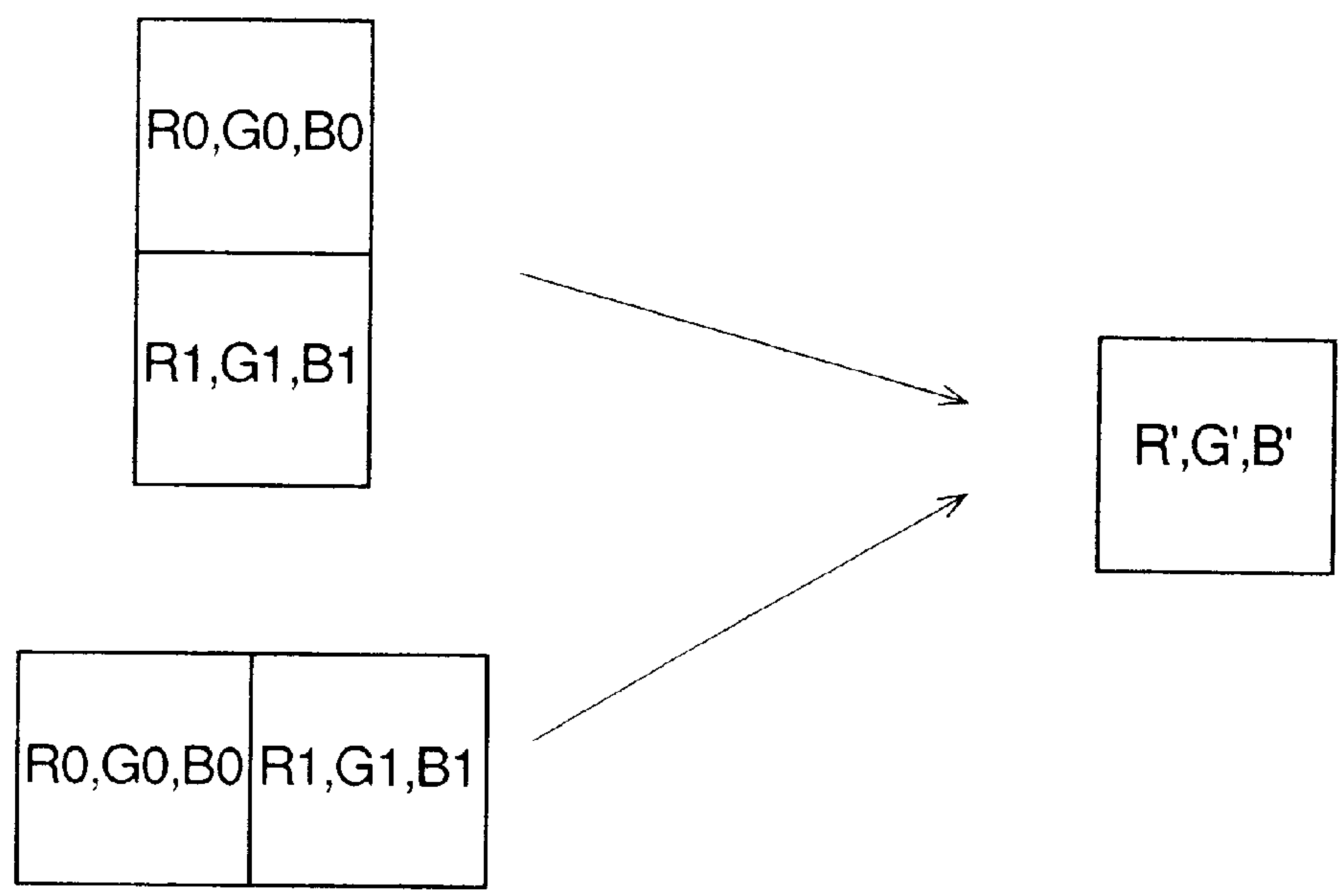

R0,G0,B0
R1,G1,B1
R',G',B'
R0,G0,B0
R1,G1,B1

FIG.5B

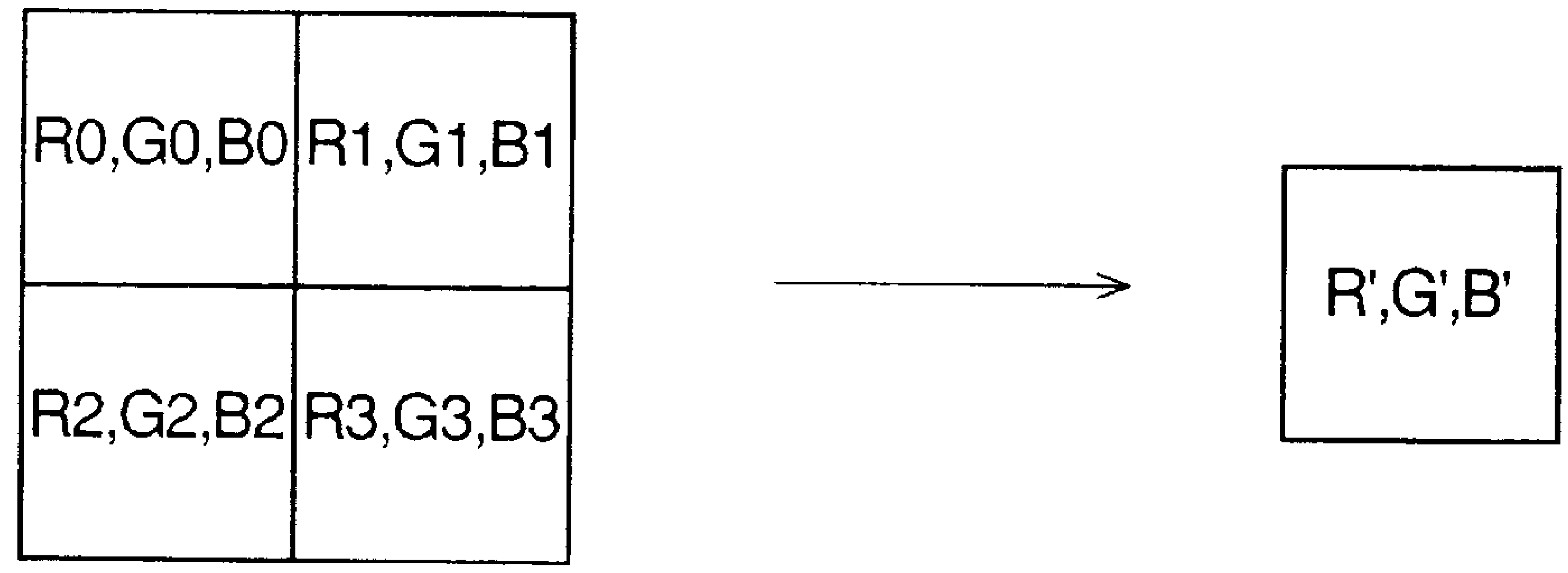

R0,G0,B0
R1,G1,B1
R2,G2,B2
R3,G3,B3
R',G',B'

FIG.6

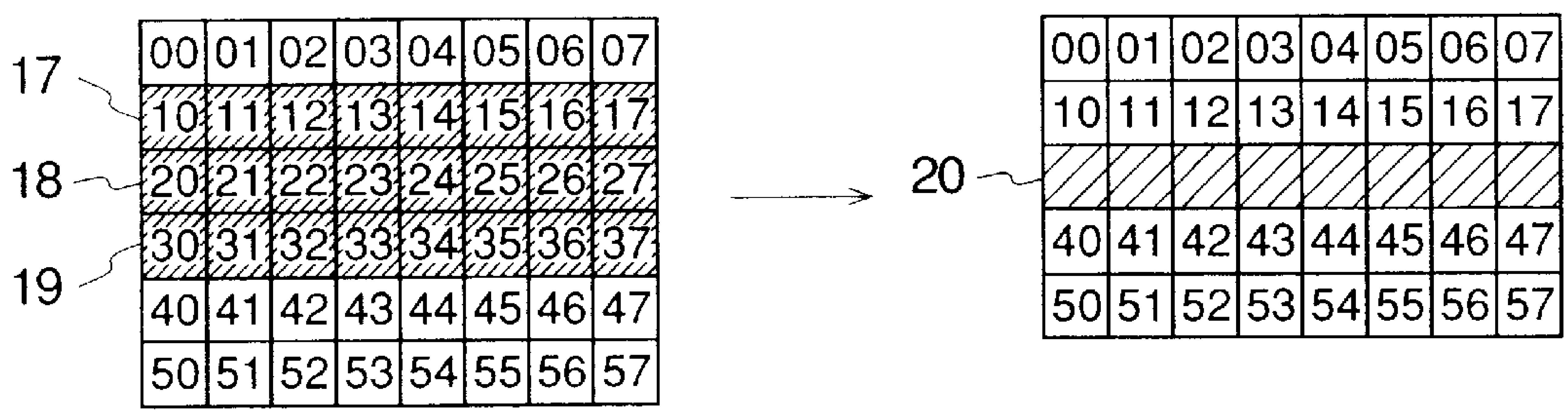

17
18
19
20
00 01 02 03 04 05 06 07
10 11 12 13 14 15 16 17
20 21 22 23 24 25 26 27
30 31 32 33 34 35 36 37
40 41 42 43 44 45 46 47
50 51 52 53 54 55 56 57
00 01 02 03 04 05 06 07
10 11 12 13 14 15 16 17
40 41 42 43 44 45 46 47
50 51 52 53 54 55 56 57

FIG.7

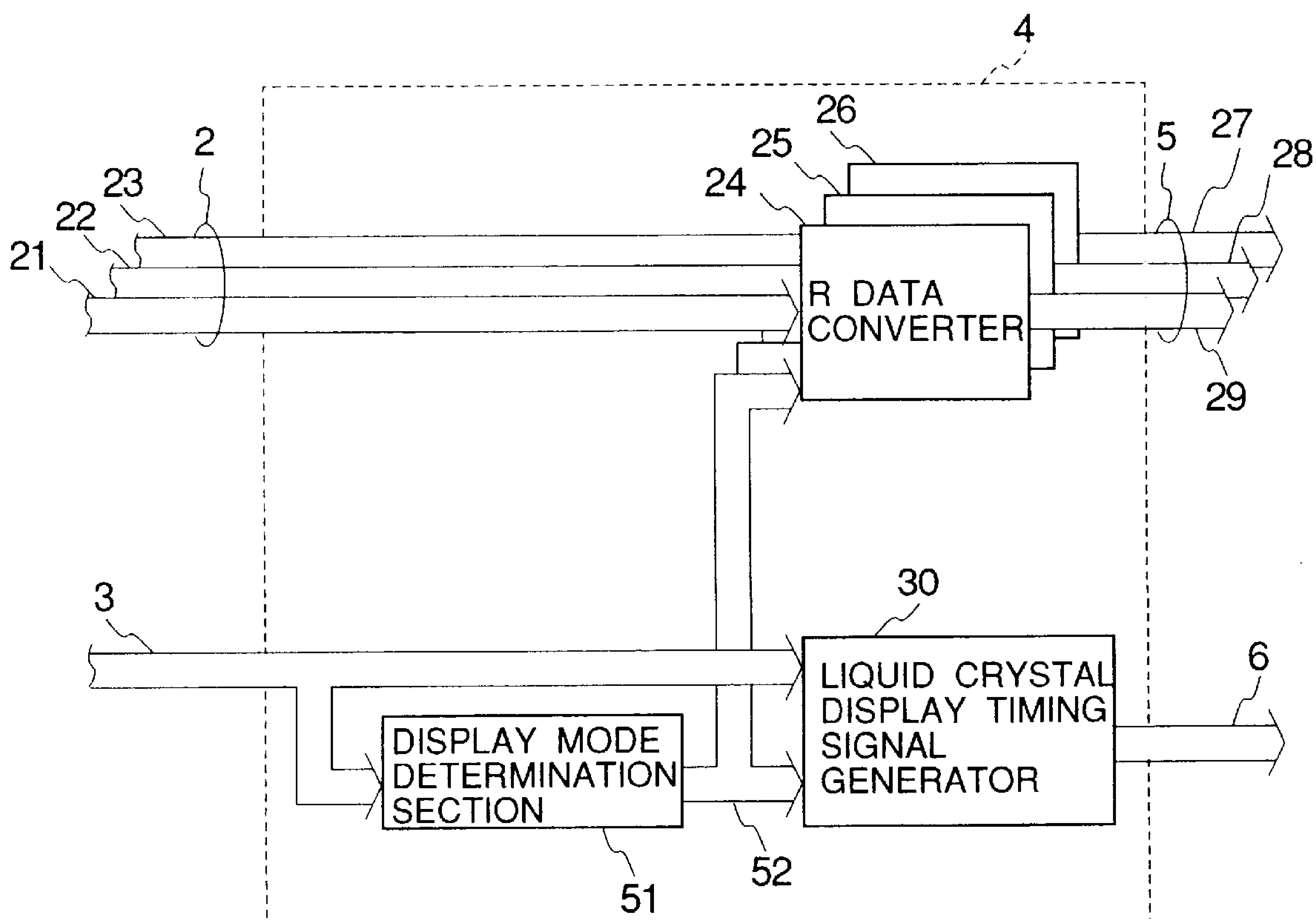

4
2
21
22
23
24
25
26
R DATA CONVERTER
5
27
28
29
3
30
LIQUID CRYSTAL DISPLAY TIMING SIGNAL GENERATOR
6
DISPLAY MODE DETERMINATION SECTION
51
52

FIG.8

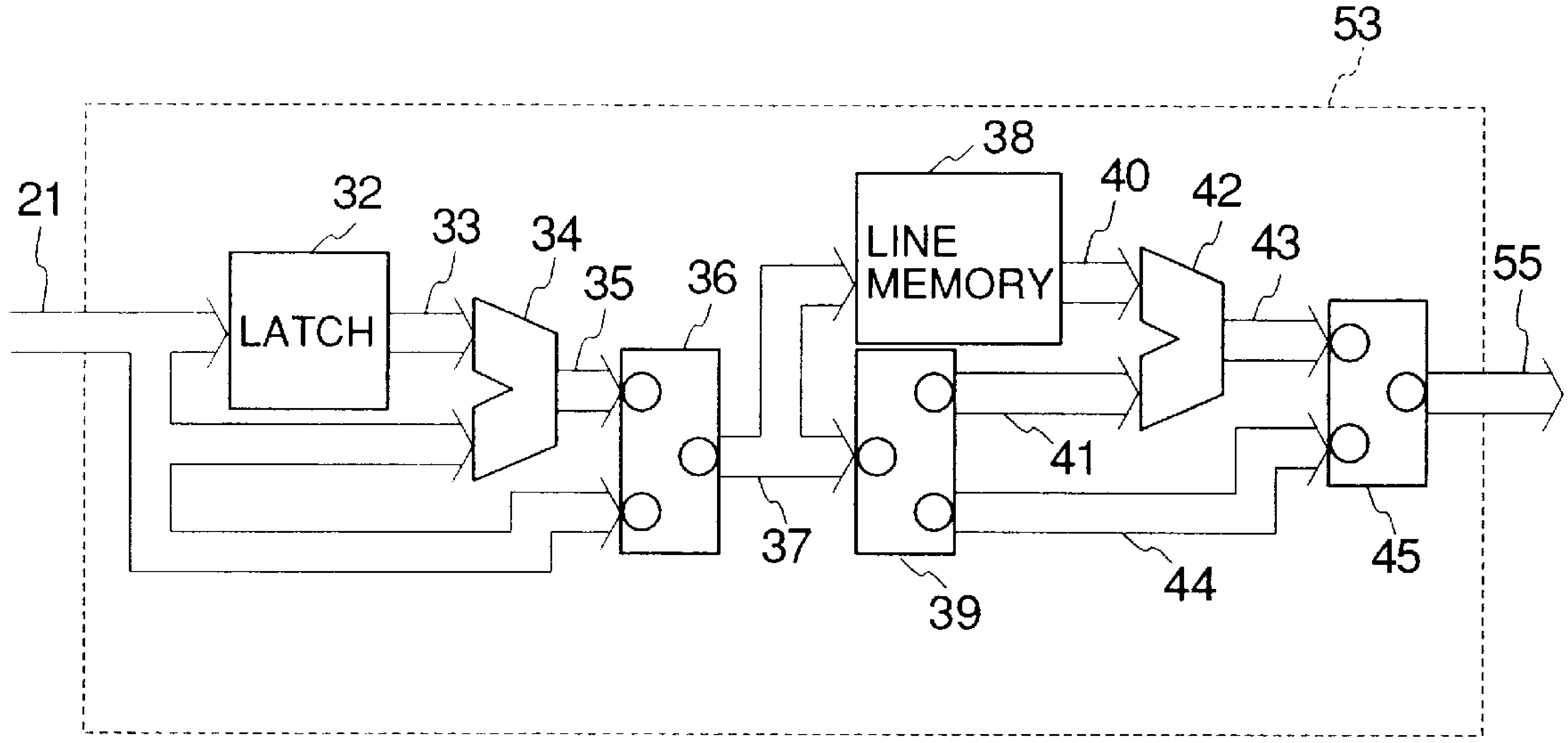

53
21
32
LATCH
33
34
35
36
38
LINE MEMORY
40
42
43
55
41
37
39
44
45

FIG.9

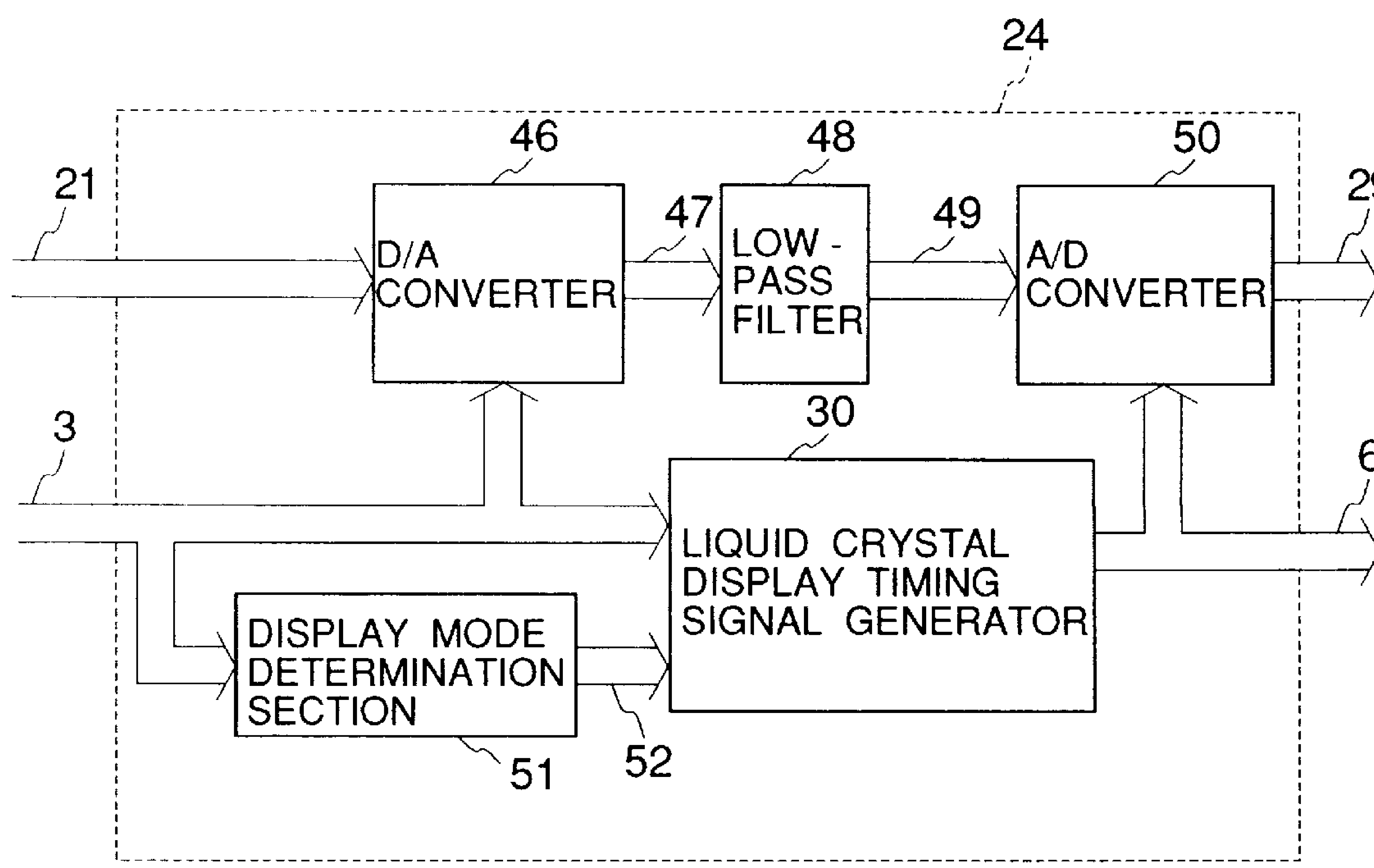

24
21
46
D/A CONVERTER
47
48
LOW - PASS FILTER
49
50
A/D CONVERTER
29
3
30
LIQUID CRYSTAL DISPLAY TIMING SIGNAL GENERATOR
6
DISPLAY MODE DETERMINATION SECTION
51
52

FIG.10

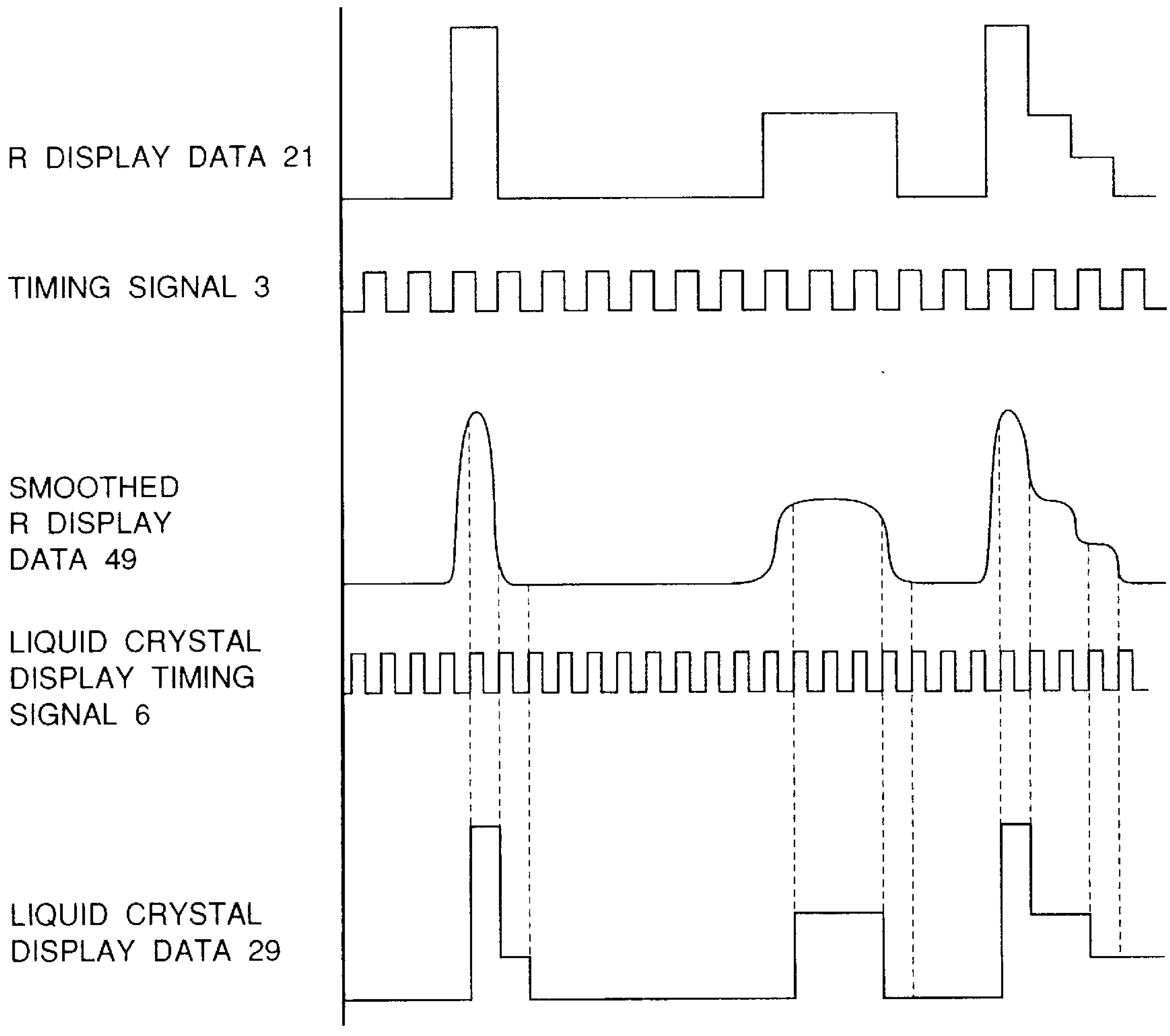

R DISPLAY DATA 21
TIMING SIGNAL 3
SMOOTHED R DISPLAY DATA 49
LIQUID CRYSTAL DISPLAY TIMING SIGNAL 6
LIQUID CRYSTAL DISPLAY DATA 29

FIG.11

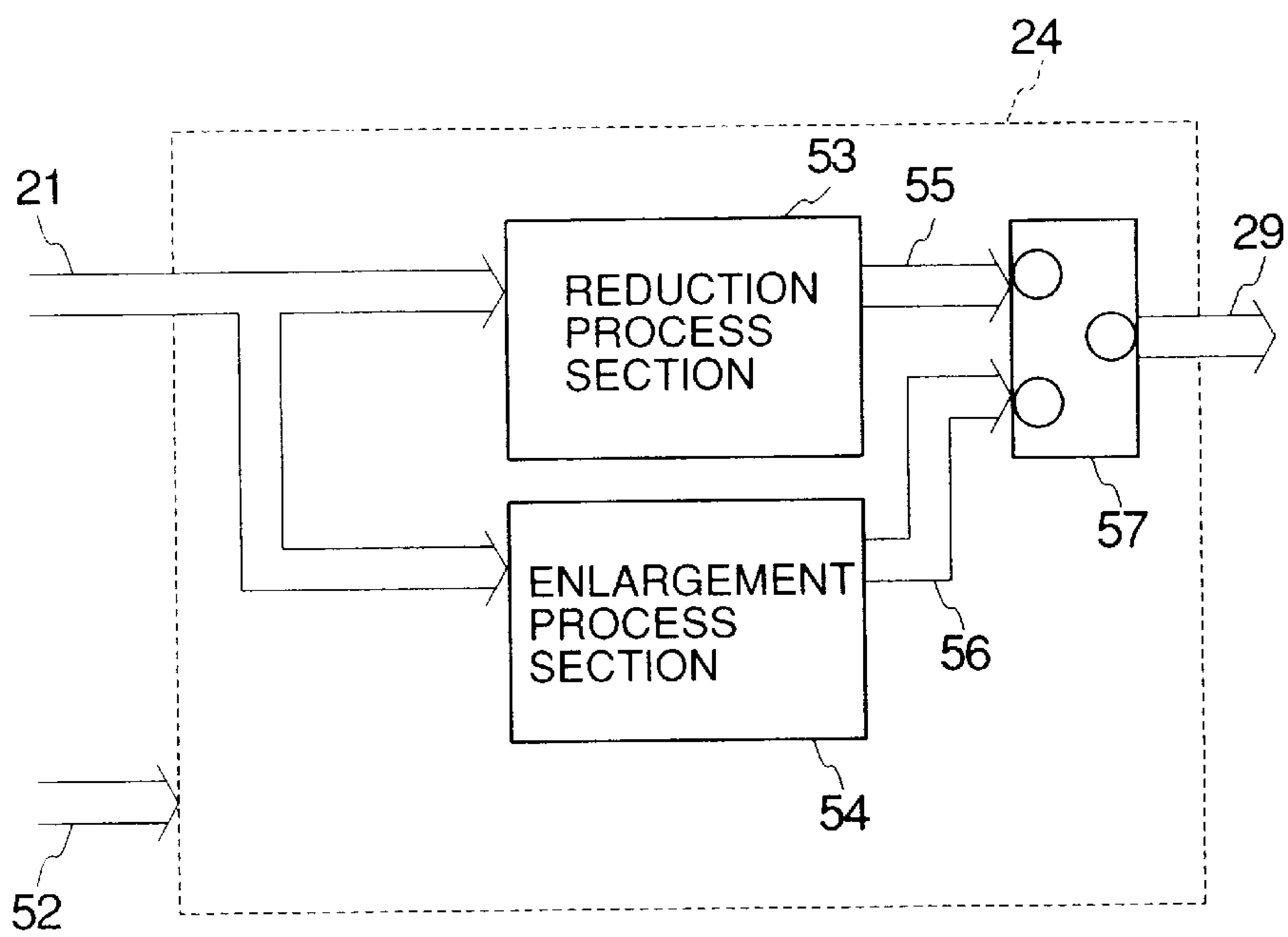

24
21
53
55
29
REDUCTION PROCESS SECTION
57
ENLARGEMENT PROCESS SECTION
56
54
52

FIG.12

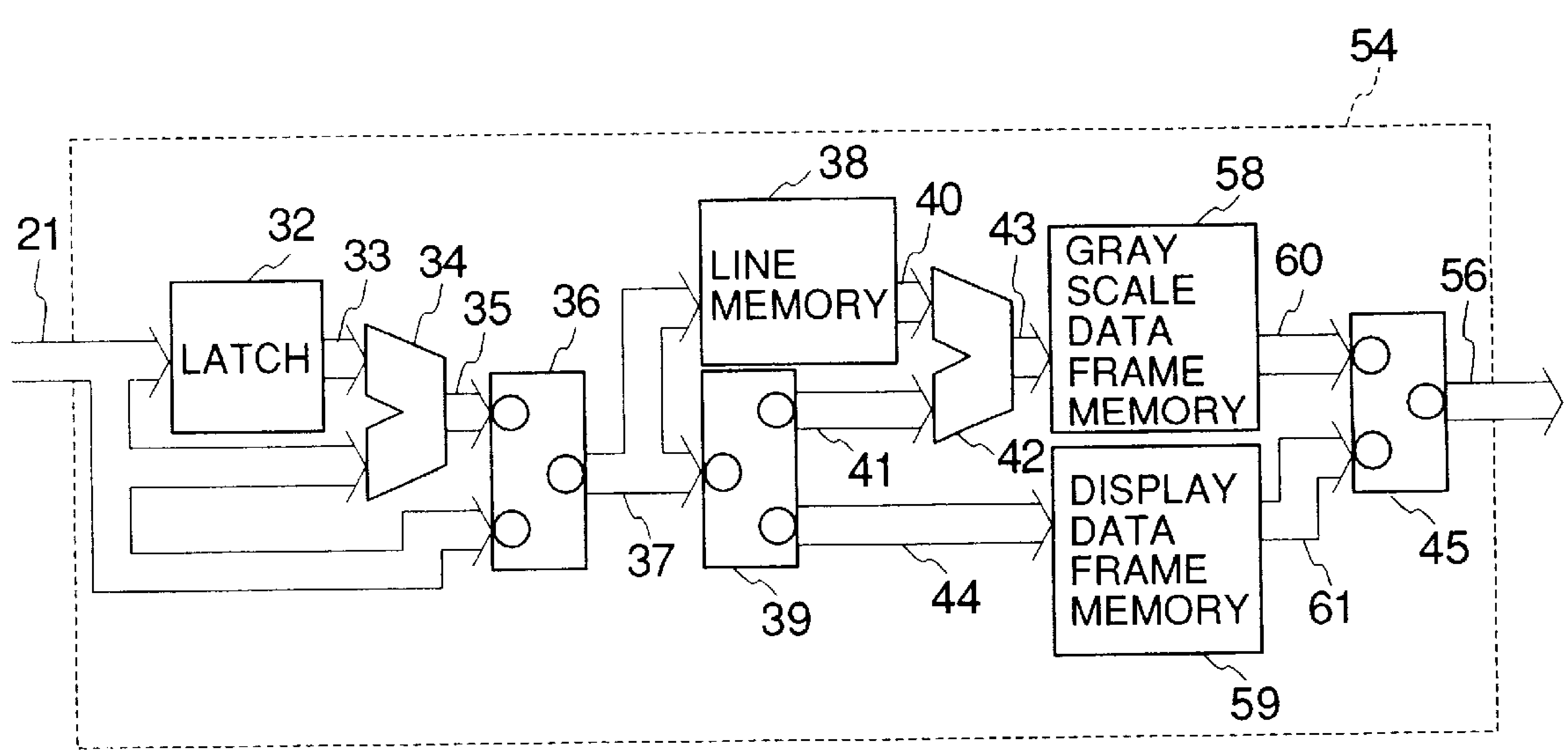

54
21
32
LATCH
33
34
35
36
38
LINE MEMORY
40
43
58
GRAY SCALE DATA FRAME MEMORY
60
56
41
42
37
39
44
DISPLAY DATA FRAME MEMORY
61
45
59

FIG.13

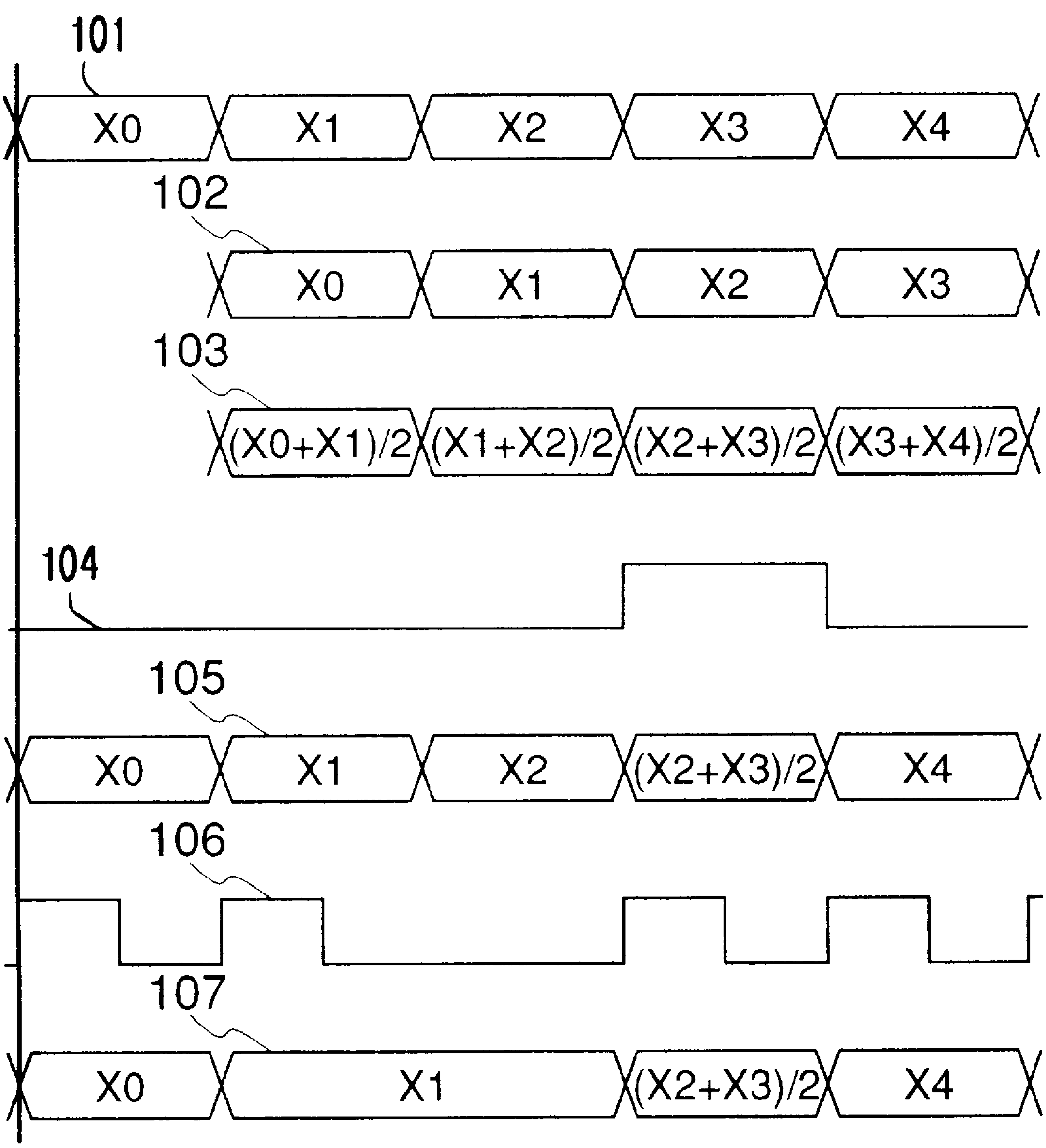

101
X0
X1
X2
X3
X4
102
X0
X1
X2
X3
103
(X0+X1)/2
(X1+X2)/2
(X2+X3)/2
(X3+X4)/2
104
105
X0
X1
X2
(X2+X3)/2
X4
106
107
X0
X1
(X2+X3)/2
X4

FIG.14

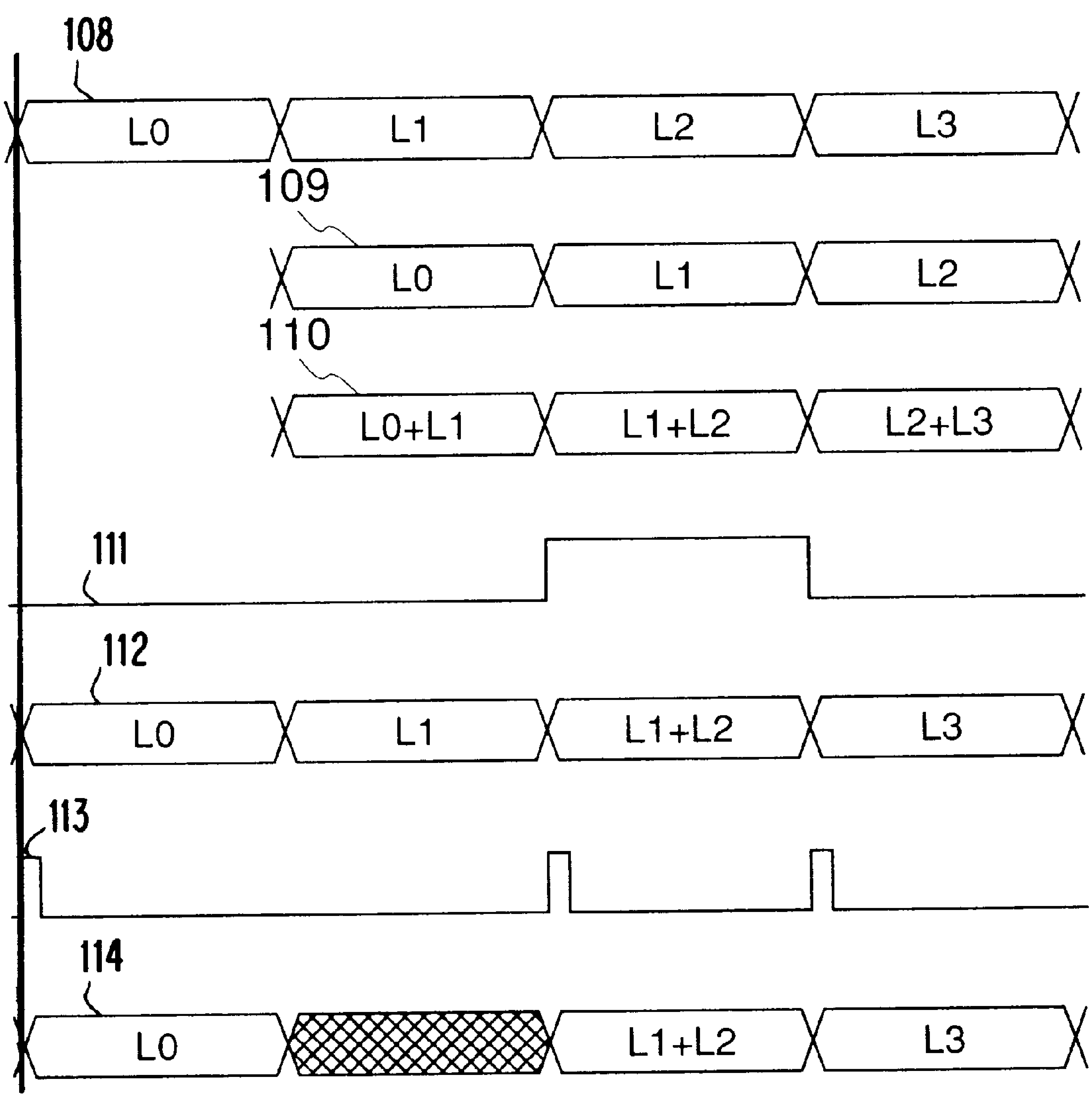

108
L0
L1
L2
L3
109
L0
L1
L2
110
L0+L1
L1+L2
L2+L3
111
112
L0
L1
L1+L2
L3
113
114
L0
L1+L2
L3

FIG.15

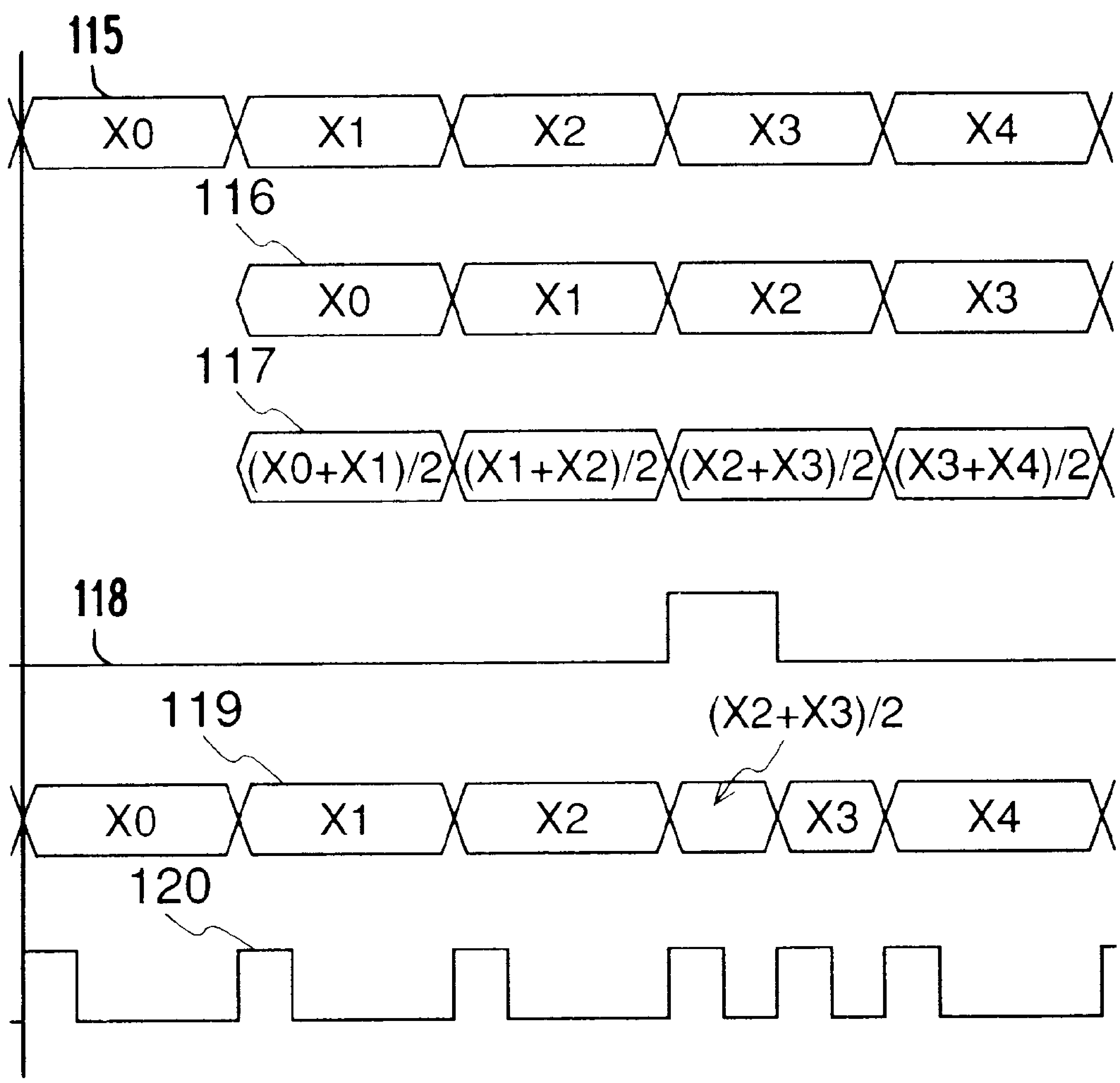

115
X0
X1
X2
X3
X4
116
X0
X1
X2
X3
117
(X0+X1)/2
(X1+X2)/2
(X2+X3)/2
(X3+X4)/2
118
119
(X2+X3)/2
X0
X1
X2
X3
X4
120

FIG.16

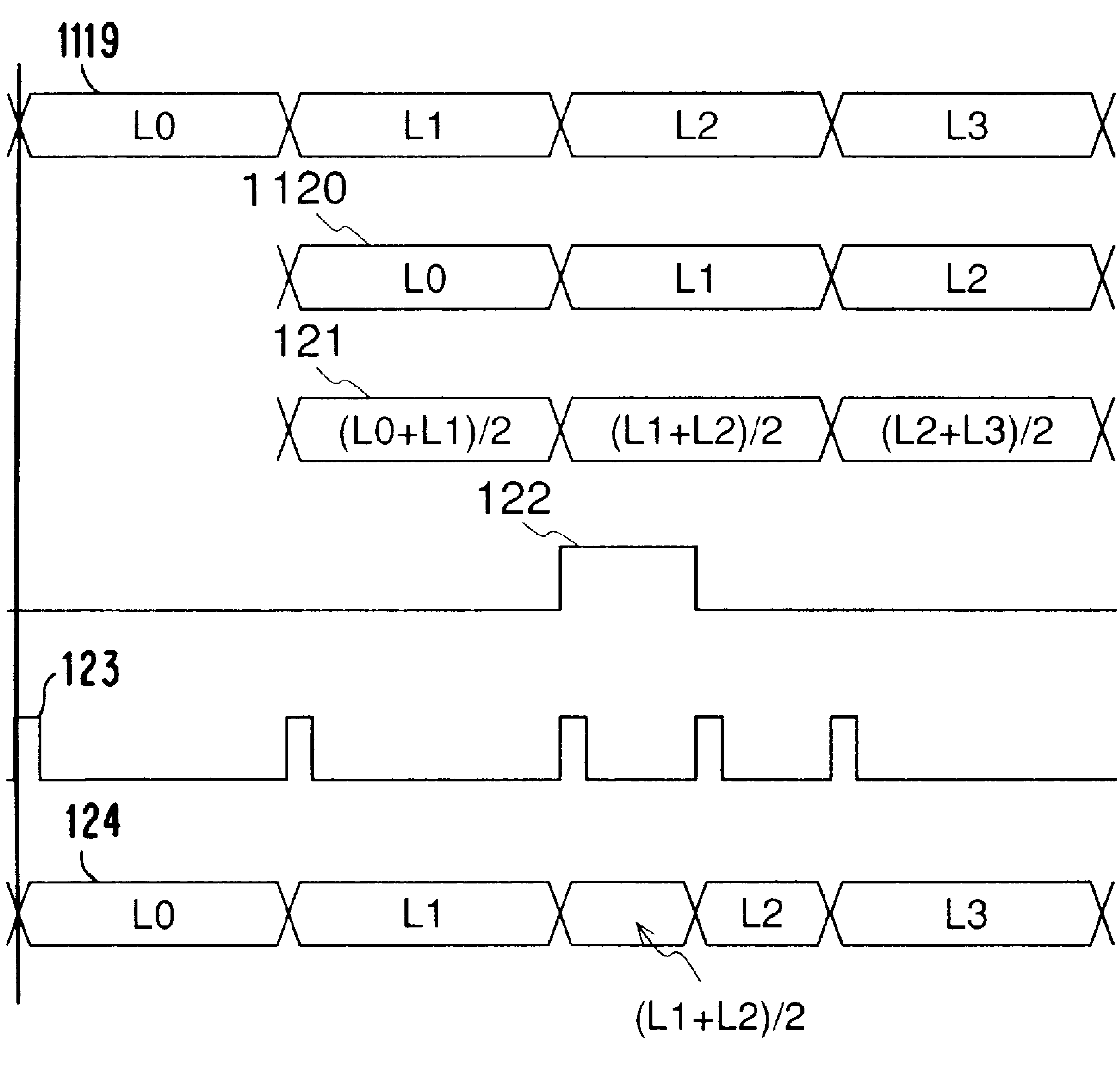

1119
L0
L1
L2
L3
1120
L0
L1
L2
121
(L0+L1)/2
(L1+L2)/2
(L2+L3)/2
122
123
124
L0
L1
L2
L3
(L1+L2)/2

FIG.17

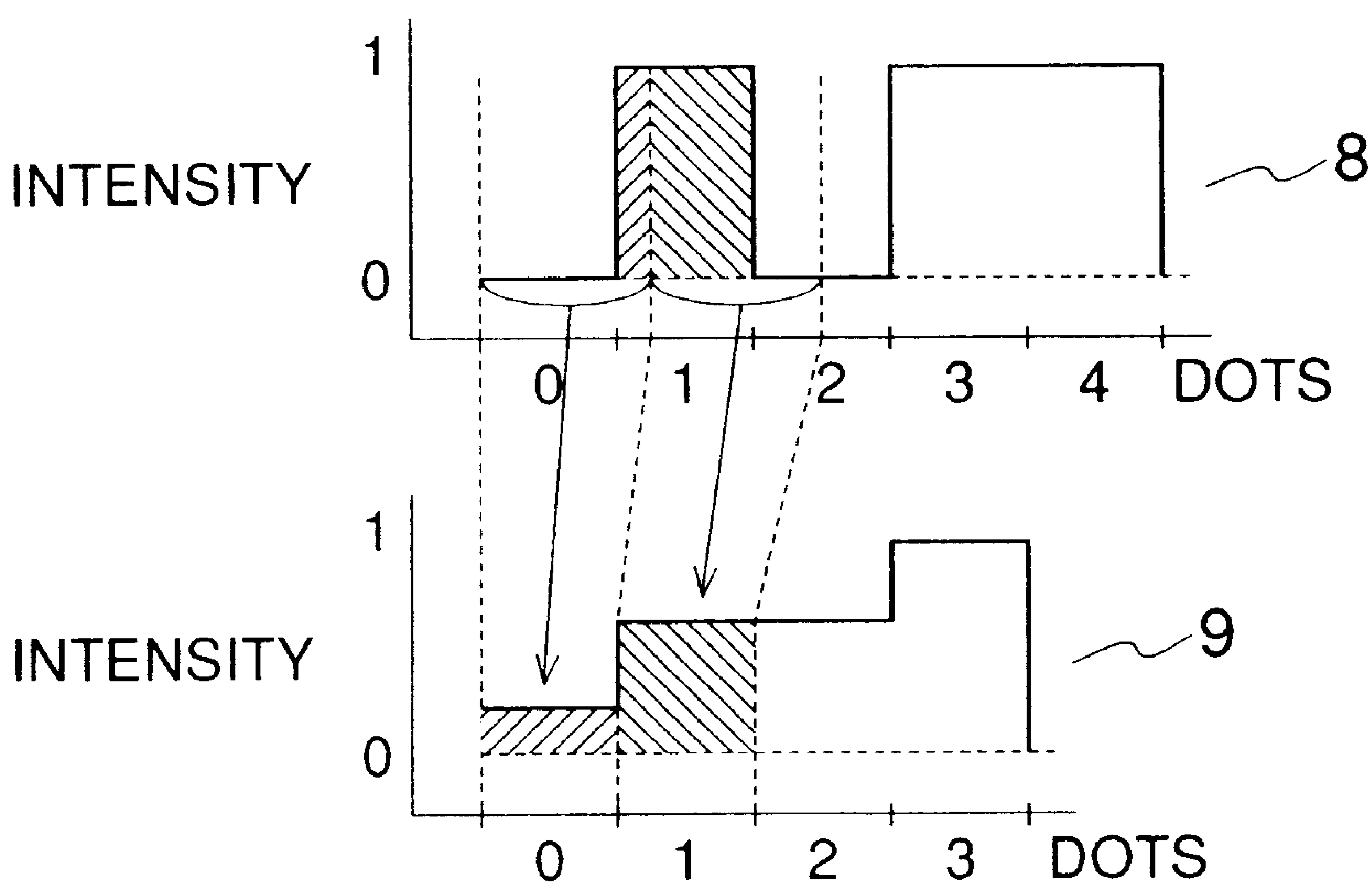


FIG.18

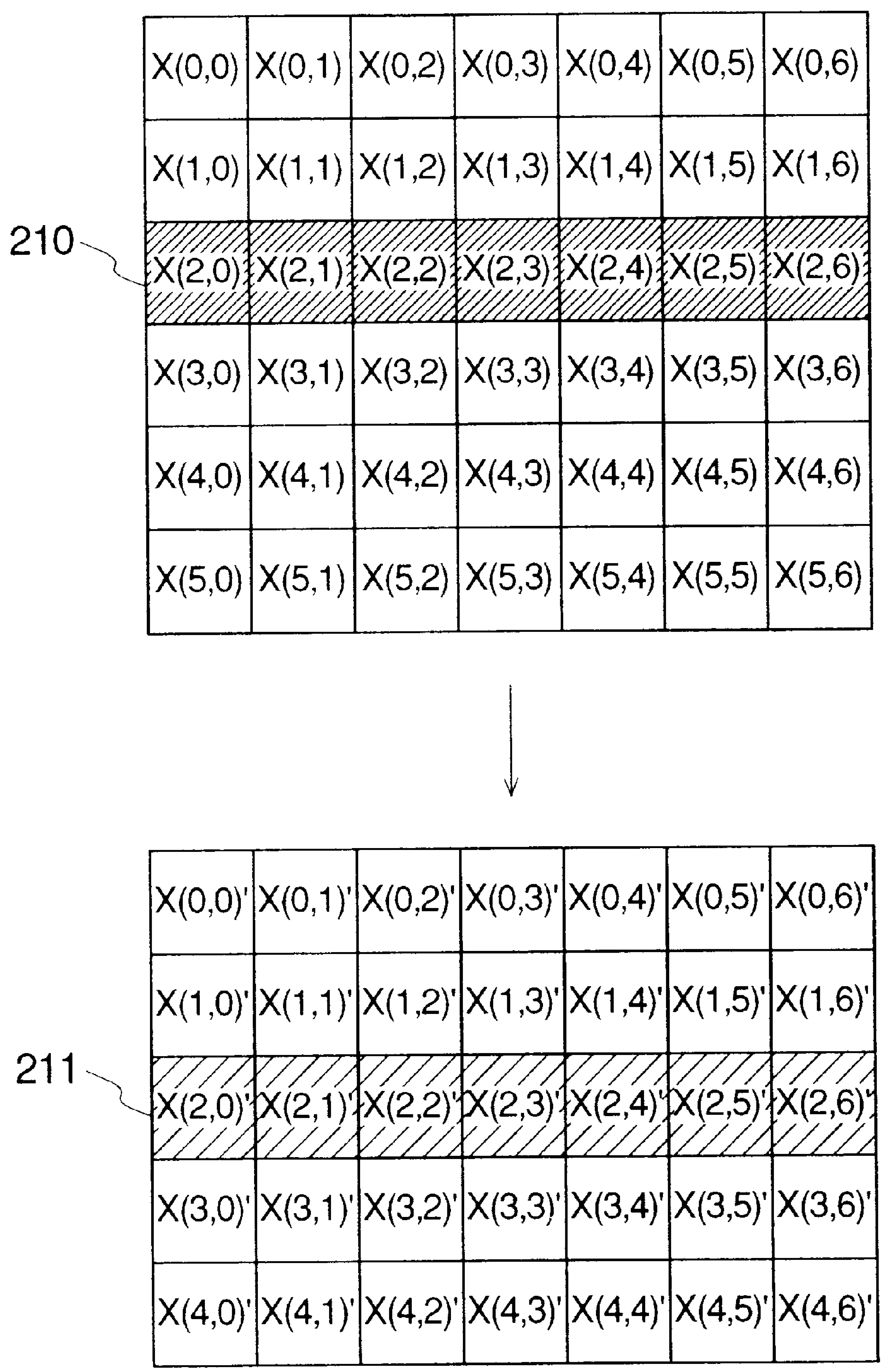

X(0,0) X(0,1) X(0,2) X(0,3) X(0,4) X(0,5) X(0,6)
X(1,0) X(1,1) X(1,2) X(1,3) X(1,4) X(1,5) X(1,6)
210
X(2,0) X(2,1) X(2,2) X(2,3) X(2,4) X(2,5) X(2,6)
X(3,0) X(3,1) X(3,2) X(3,3) X(3,4) X(3,5) X(3,6)
X(4,0) X(4,1) X(4,2) X(4,3) X(4,4) X(4,5) X(4,6)
X(5,0) X(5,1) X(5,2) X(5,3) X(5,4) X(5,5) X(5,6)
X(0,0)' X(0,1)' X(0,2)' X(0,3)' X(0,4)' X(0,5)' X(0,6)'
X(1,0)' X(1,1)' X(1,2)' X(1,3)' X(1,4)' X(1,5)' X(1,6)'
211
X(2,0)' X(2,1)' X(2,2)' X(2,3)' X(2,4)' X(2,5)' X(2,6)'
X(3,0)' X(3,1)' X(3,2)' X(3,3)' X(3,4)' X(3,5)' X(3,6)'
X(4,0)' X(4,1)' X(4,2)' X(4,3)' X(4,4)' X(4,5)' X(4,6)'

FIG.19

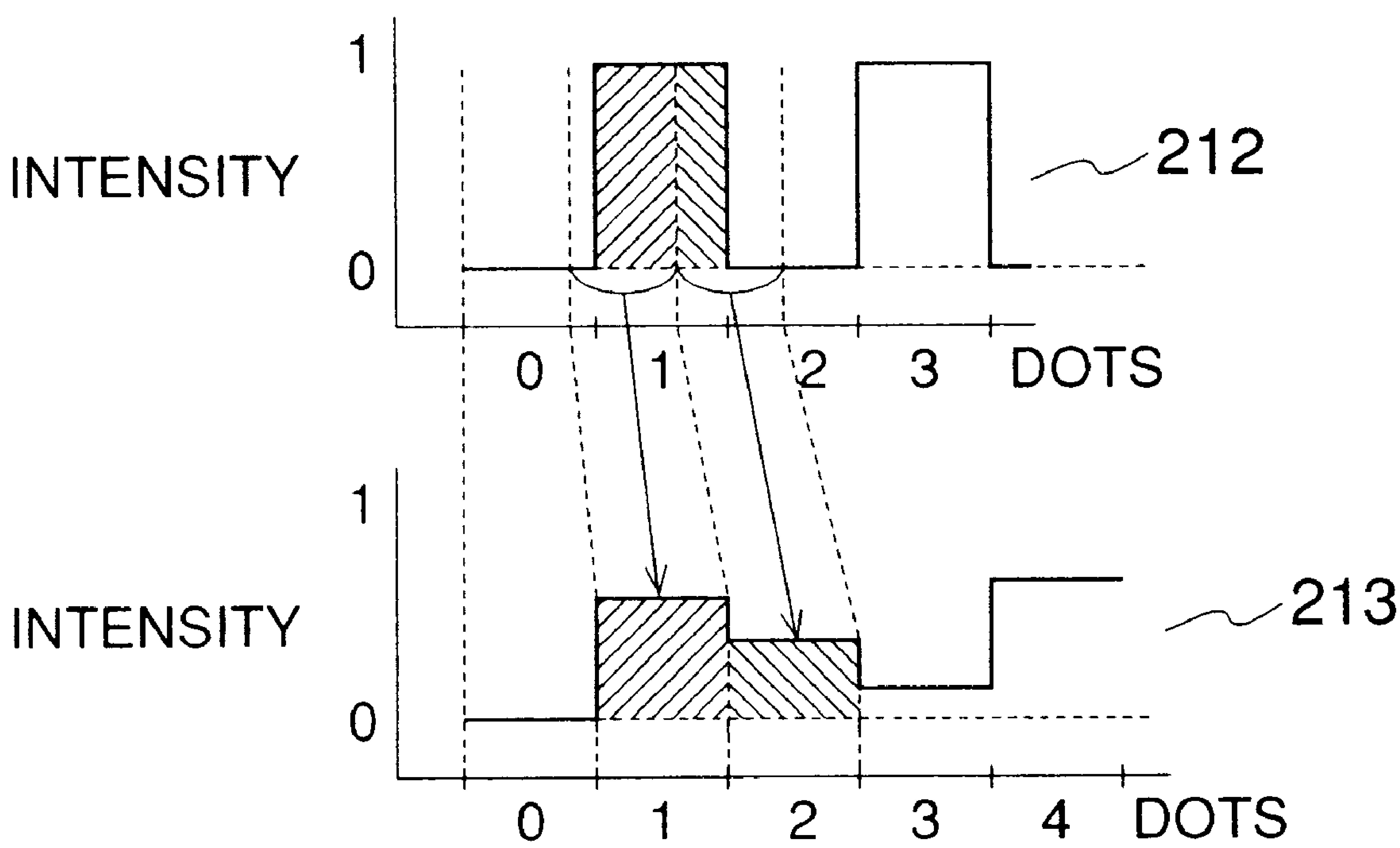


FIG.20

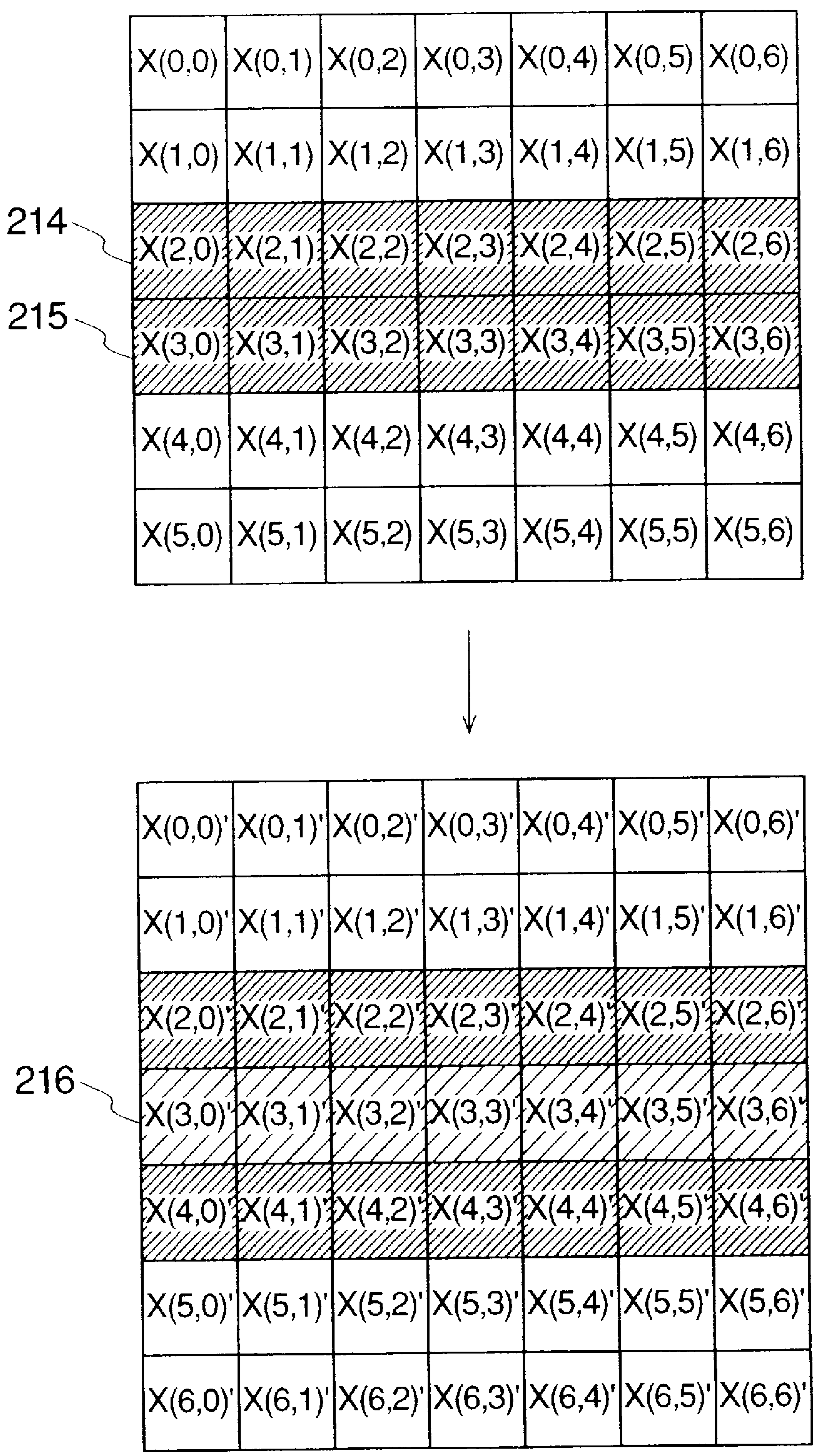

X(0,0) X(0,1) X(0,2) X(0,3) X(0,4) X(0,5) X(0,6)
X(1,0) X(1,1) X(1,2) X(1,3) X(1,4) X(1,5) X(1,6)
214
X(2,0) X(2,1) X(2,2) X(2,3) X(2,4) X(2,5) X(2,6)
215
X(3,0) X(3,1) X(3,2) X(3,3) X(3,4) X(3,5) X(3,6)
X(4,0) X(4,1) X(4,2) X(4,3) X(4,4) X(4,5) X(4,6)
X(5,0) X(5,1) X(5,2) X(5,3) X(5,4) X(5,5) X(5,6)
X(0,0)' X(0,1)' X(0,2)' X(0,3)' X(0,4)' X(0,5)' X(0,6)'
X(1,0)' X(1,1)' X(1,2)' X(1,3)' X(1,4)' X(1,5)' X(1,6)'
X(2,0)' X(2,1)' X(2,2)' X(2,3)' X(2,4)' X(2,5)' X(2,6)'
216
X(3,0)' X(3,1)' X(3,2)' X(3,3)' X(3,4)' X(3,5)' X(3,6)'
X(4,0)' X(4,1)' X(4,2)' X(4,3)' X(4,4)' X(4,5)' X(4,6)'
X(5,0)' X(5,1)' X(5,2)' X(5,3)' X(5,4)' X(5,5)' X(5,6)'
X(6,0)' X(6,1)' X(6,2)' X(6,3)' X(6,4)' X(6,5)' X(6,6)'

FIG.21

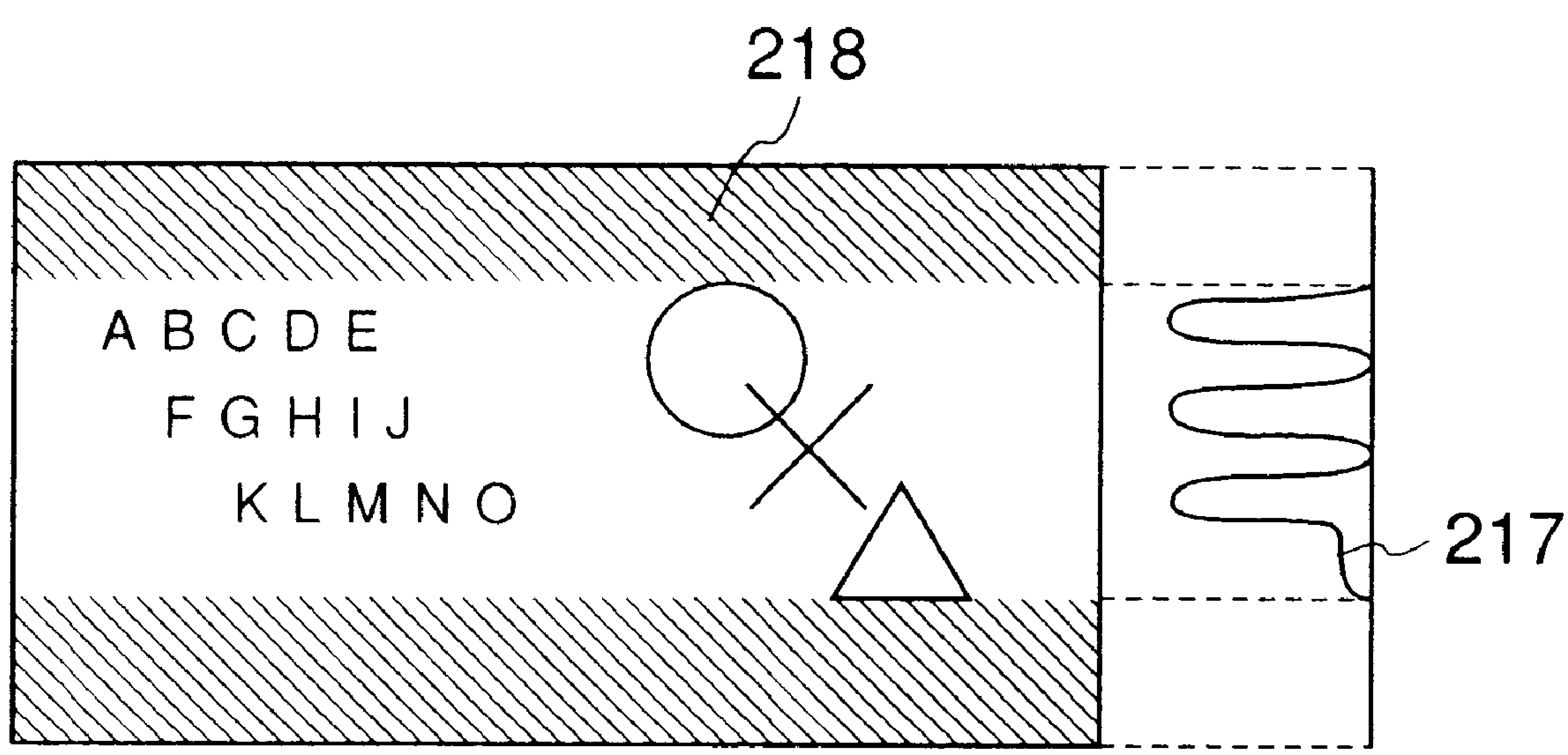
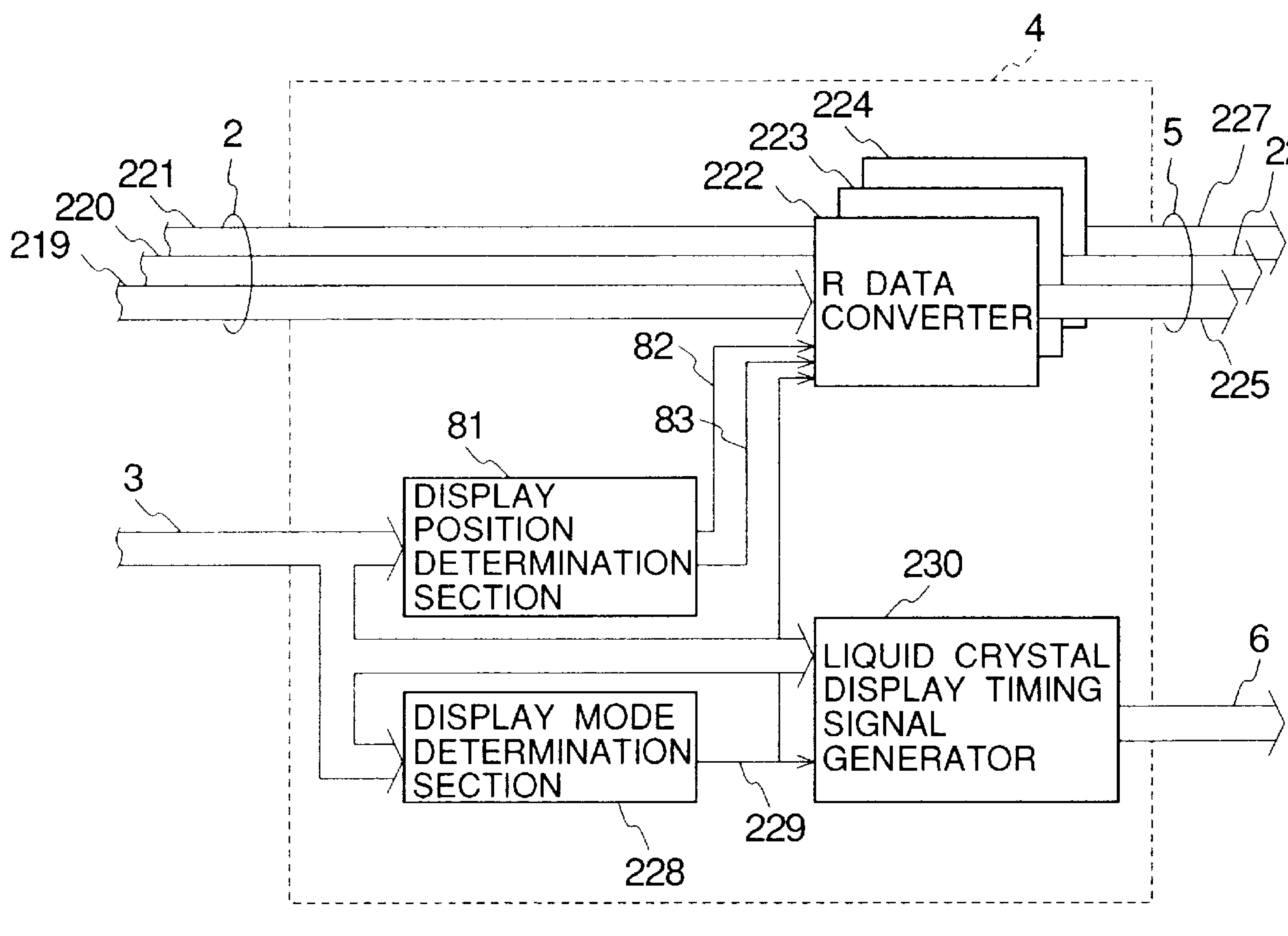


FIG.22



4
2
221
220
219
224
223
222
R DATA CONVERTER
5
227
226
225
82
83
81
3
DISPLAY POSITION DETERMINATION SECTION
230
LIQUID CRYSTAL DISPLAY TIMING SIGNAL GENERATOR
6
DISPLAY MODE DETERMINATION SECTION
229
228

FIG.23

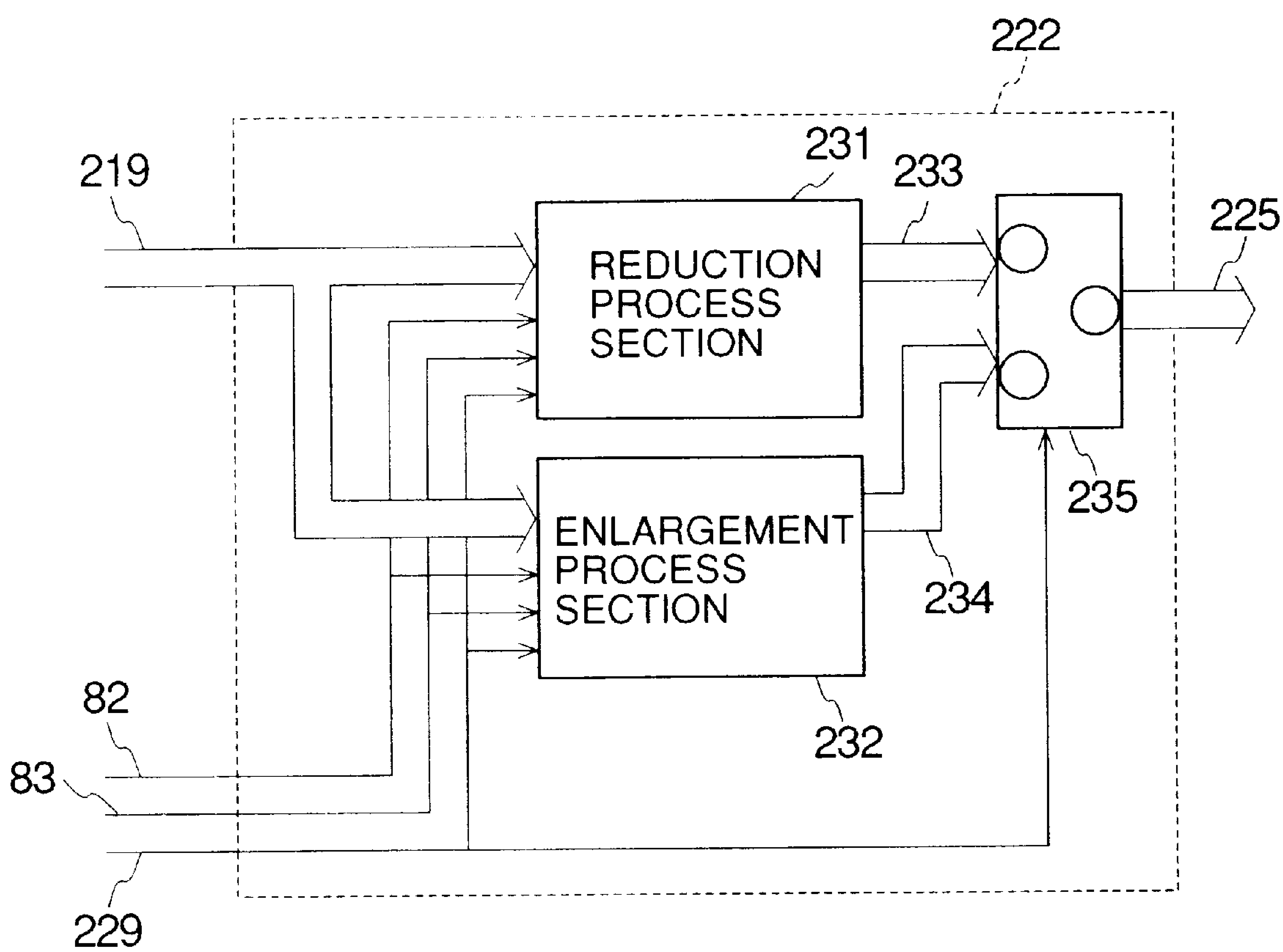

222
231
233
219
225
REDUCTION
PROCESS
SECTION
235
ENLARGEMENT
PROCESS
SECTION
234
82
232
83
229

FIG.24

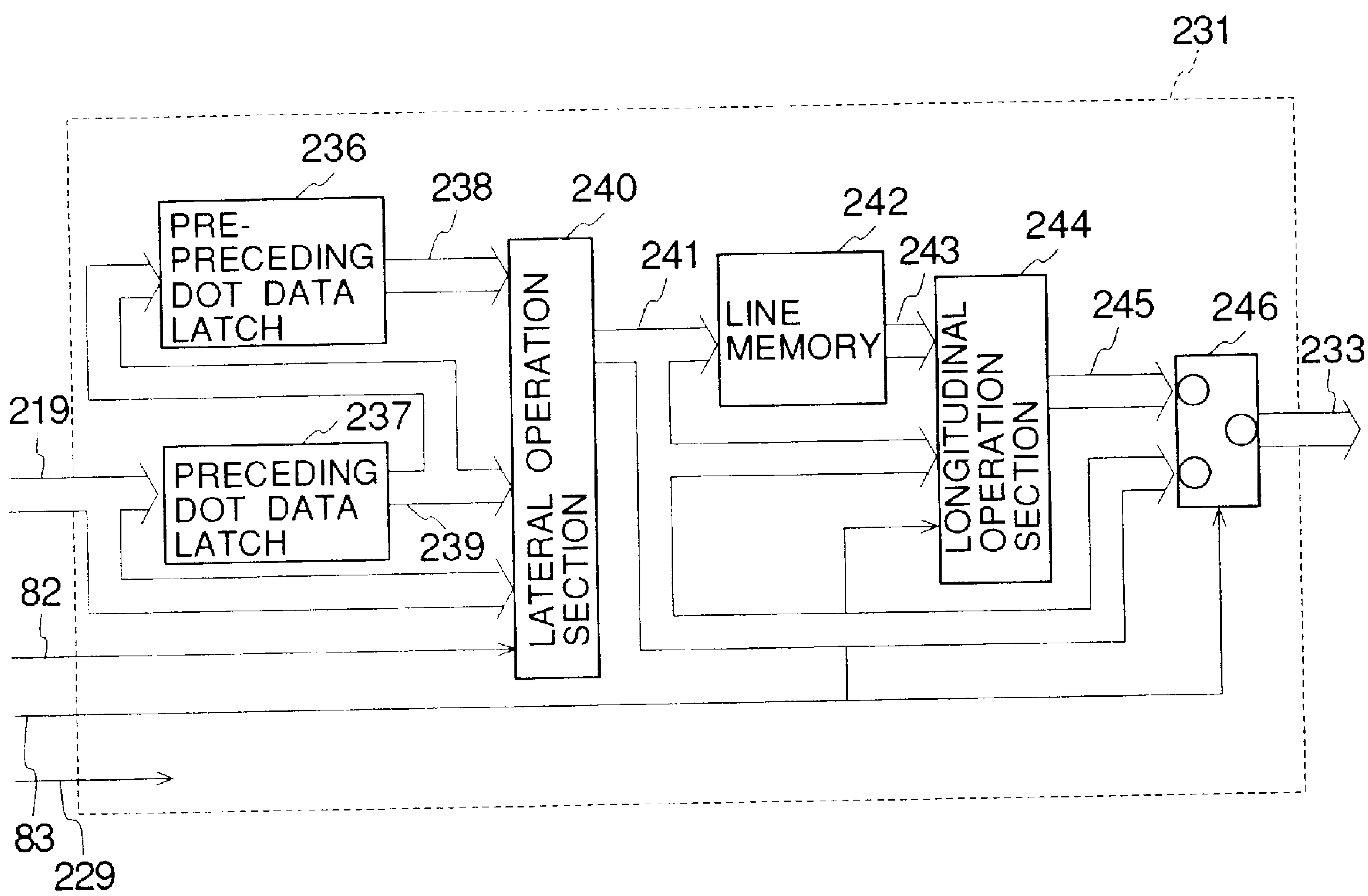

231
236
PRE-PRECEDING DOT DATA LATCH
238
240
LATERAL OPERATION SECTION
241
242
LINE MEMORY
243
244
LONGITUDINAL OPERATION SECTION
245
246
233
219
237
PRECEDING DOT DATA LATCH
239
82
83
229

FIG.25

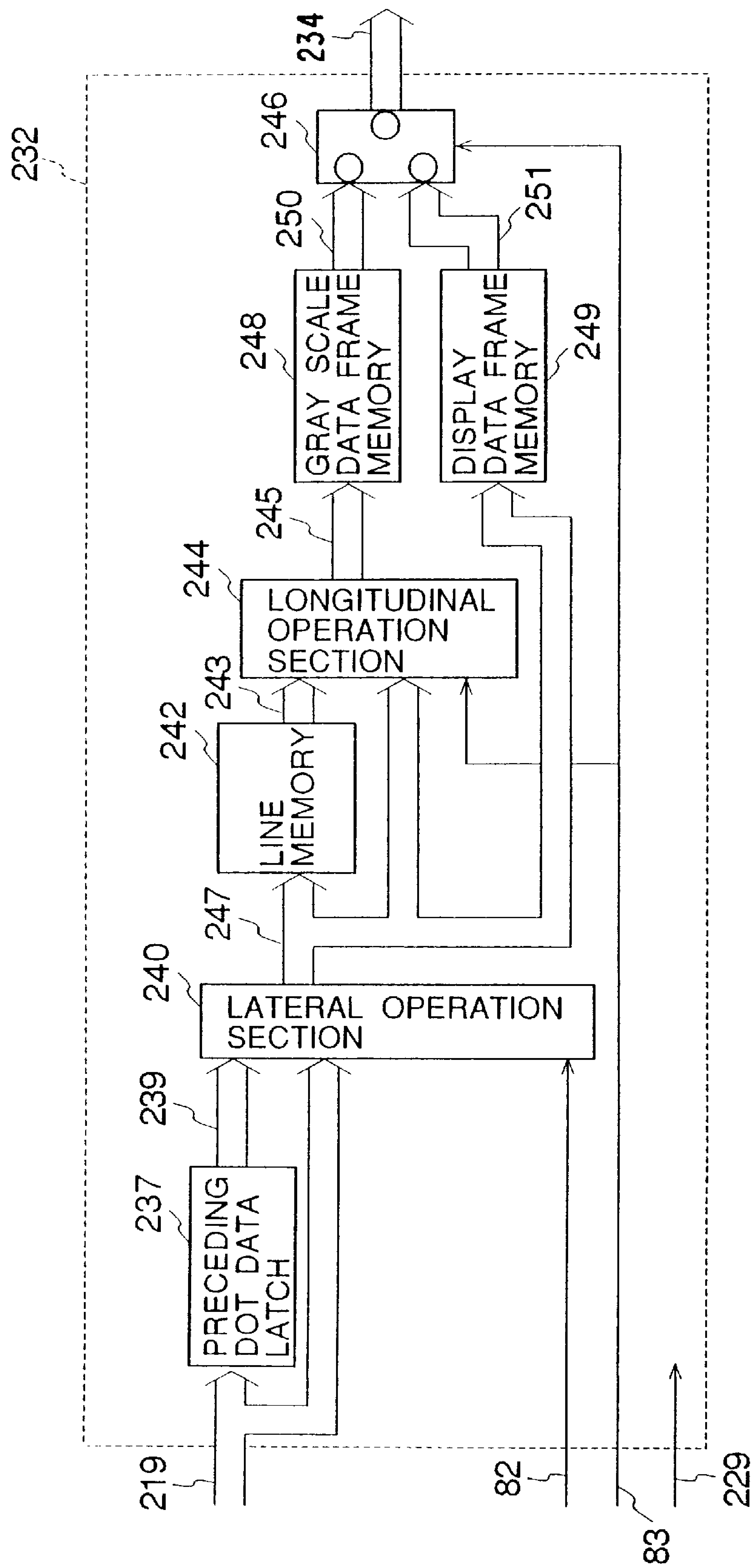

234
232
246
250
251
248
GRAY SCALE DATA FRAME MEMORY
249
DISPLAY DATA FRAME MEMORY
245
244
LONGITUDINAL OPERATION SECTION
243
242
LINE MEMORY
247
240
LATERAL OPERATION SECTION
239
237
PRECEDING DOT DATA LATCH
219
82
83
229

FIG.26

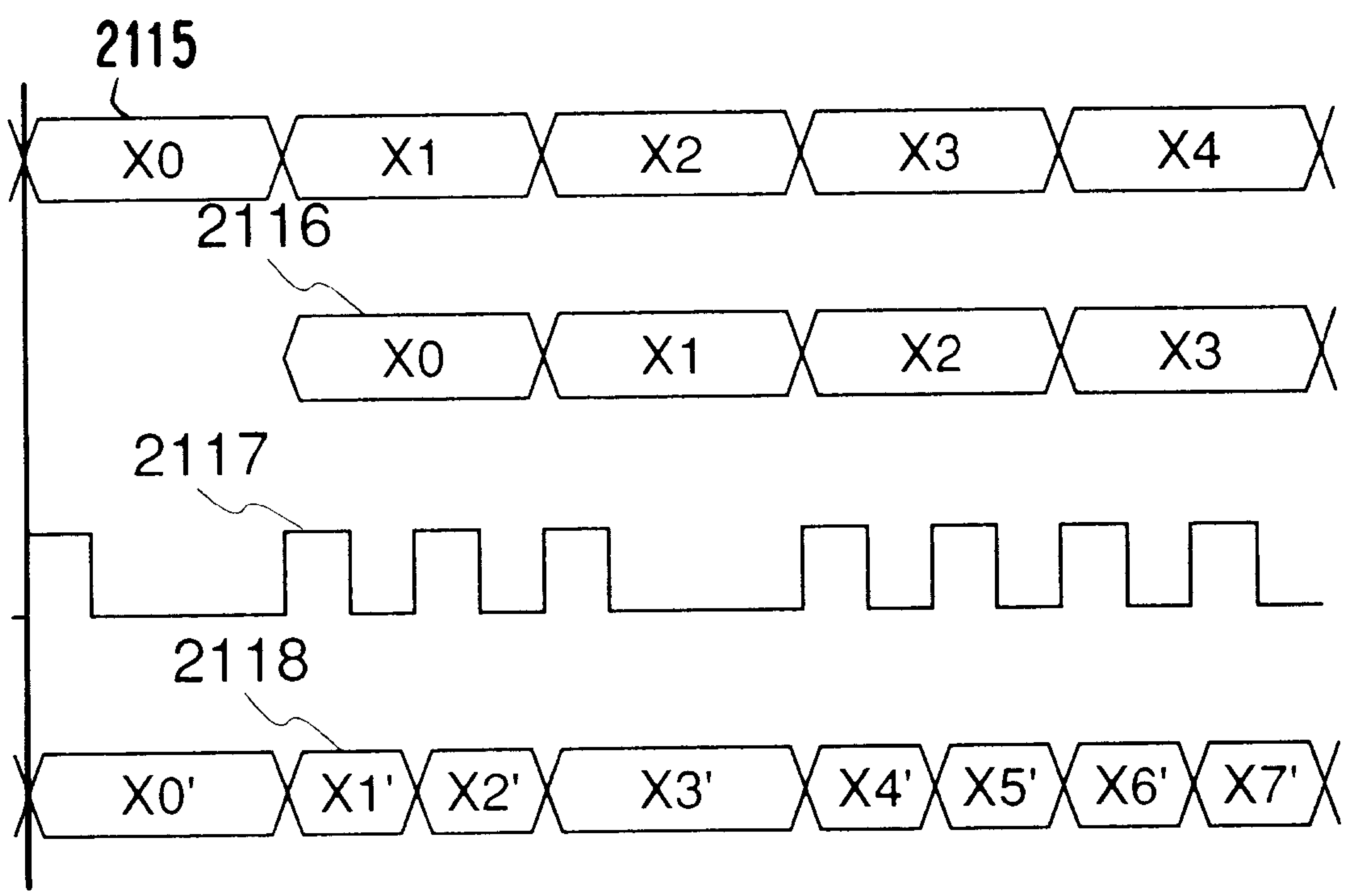

2115
X0
X1
X2
X3
X4
2116
X0
X1
X2
X3
2117
2118
X0'
X1'
X2'
X3'
X4'
X5'
X6'
X7'

FIG.27

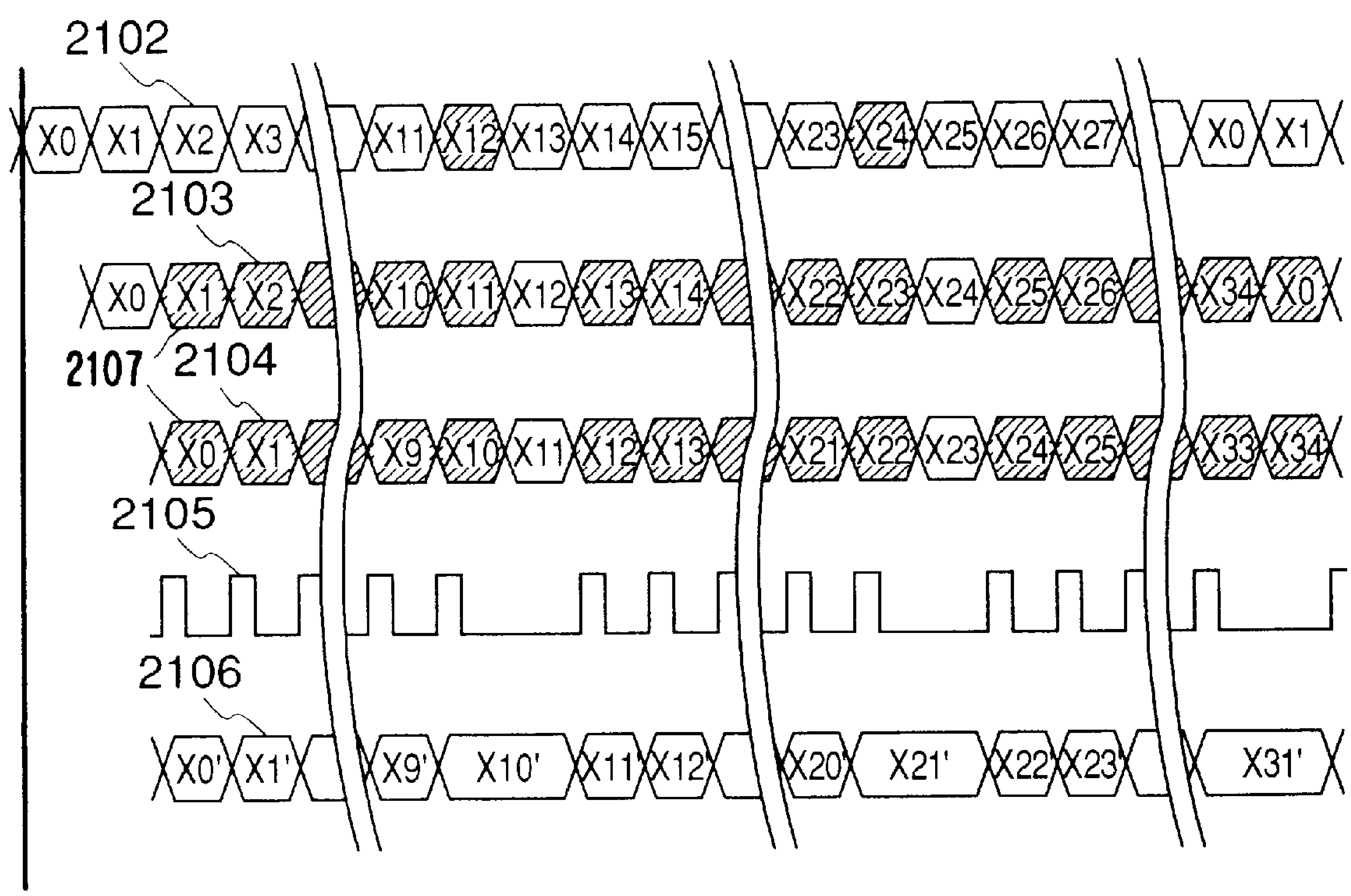

2102
X0
X1
X2
X3
X11
X12
X13
X14
X15
X23
X24
X25
X26
X27
X0
X1
2103
X0
X1
X2
X10
X11
X12
X13
X14
X22
X23
X24
X25
X26
X34
X0
2107
2104
X0'
X1'
X9
X10
X11
X12
X13
X21
X22
X23
X24
X25
X33
X34
2105
2106
X0'
X1'
X9'
X10'
X11'
X12'
X20'
X21'
X22'
X23'
X31'

FIG.28

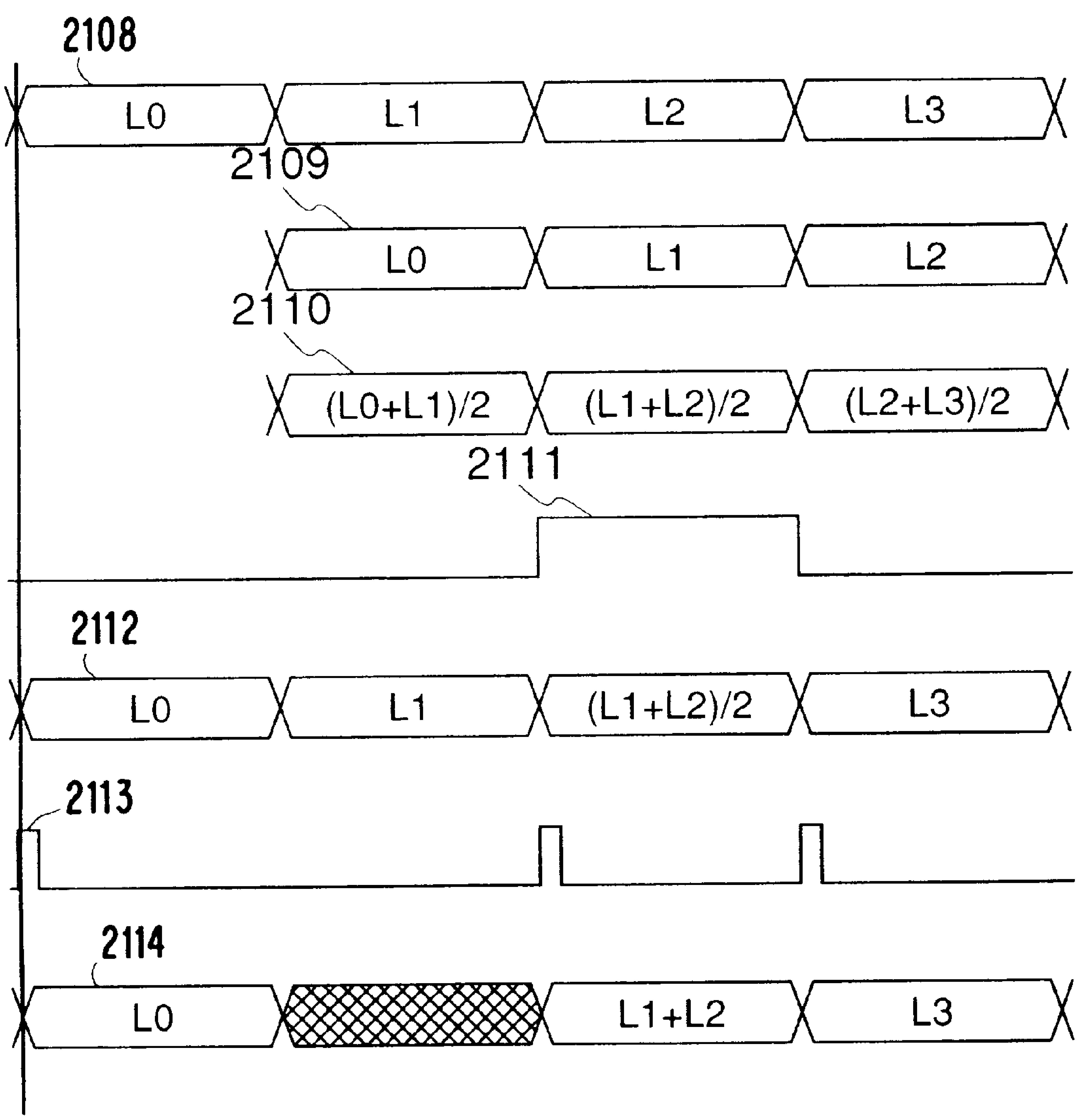

2108
L0
L1
L2
L3
2109
L0
L1
L2
2110
(L0+L1)/2
(L1+L2)/2
(L2+L3)/2
2111
2112
L0
L1
(L1+L2)/2
L3
2113
2114
L0
L1+L2
L3

FIG.29

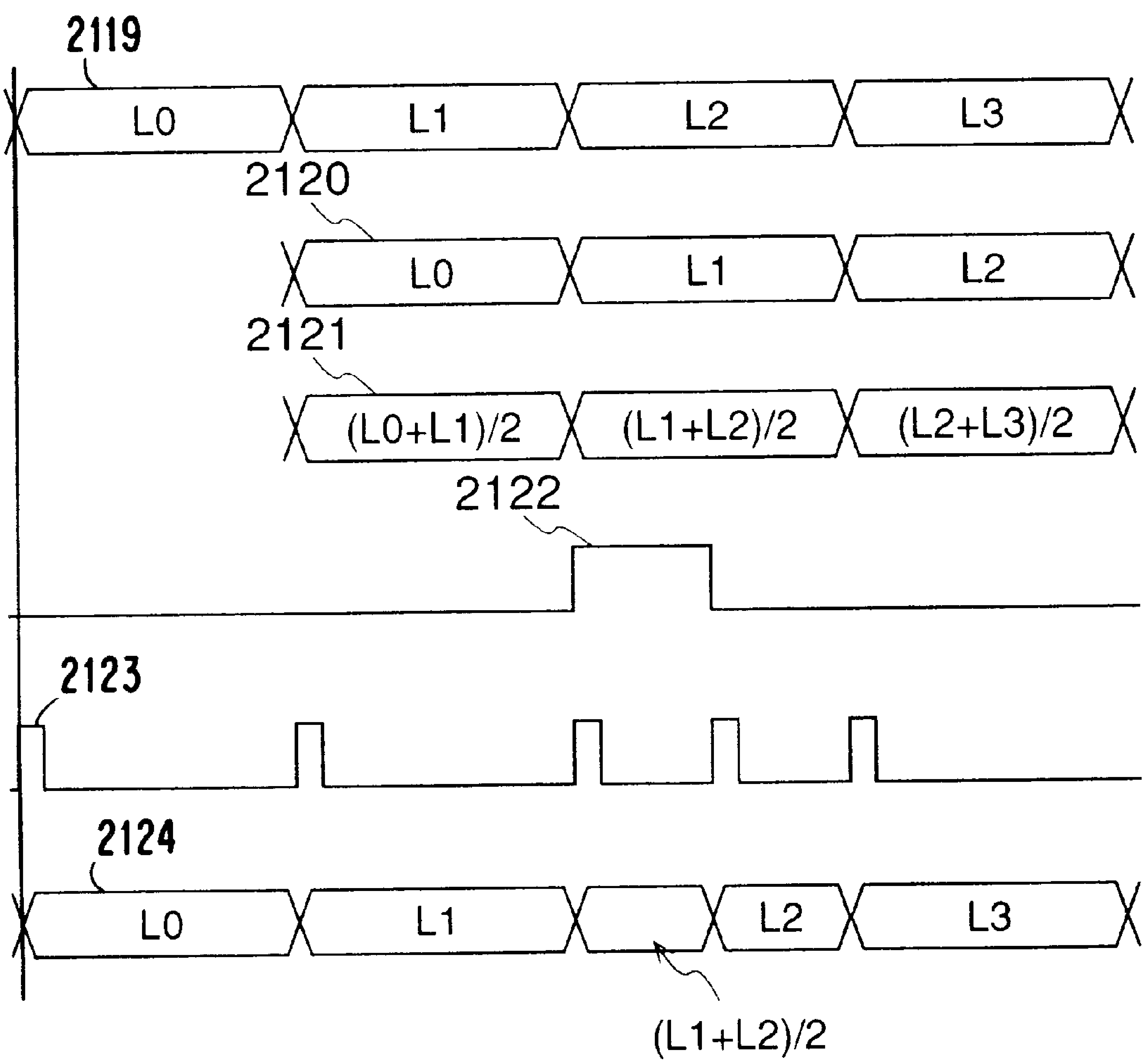

2119
L0
L1
L2
L3
2120
L0
L1
L2
2121
(L0+L1)/2
(L1+L2)/2
(L2+L3)/2
2122
2123
2124
L0
L1
L2
L3
(L1+L2)/2

FIG.30

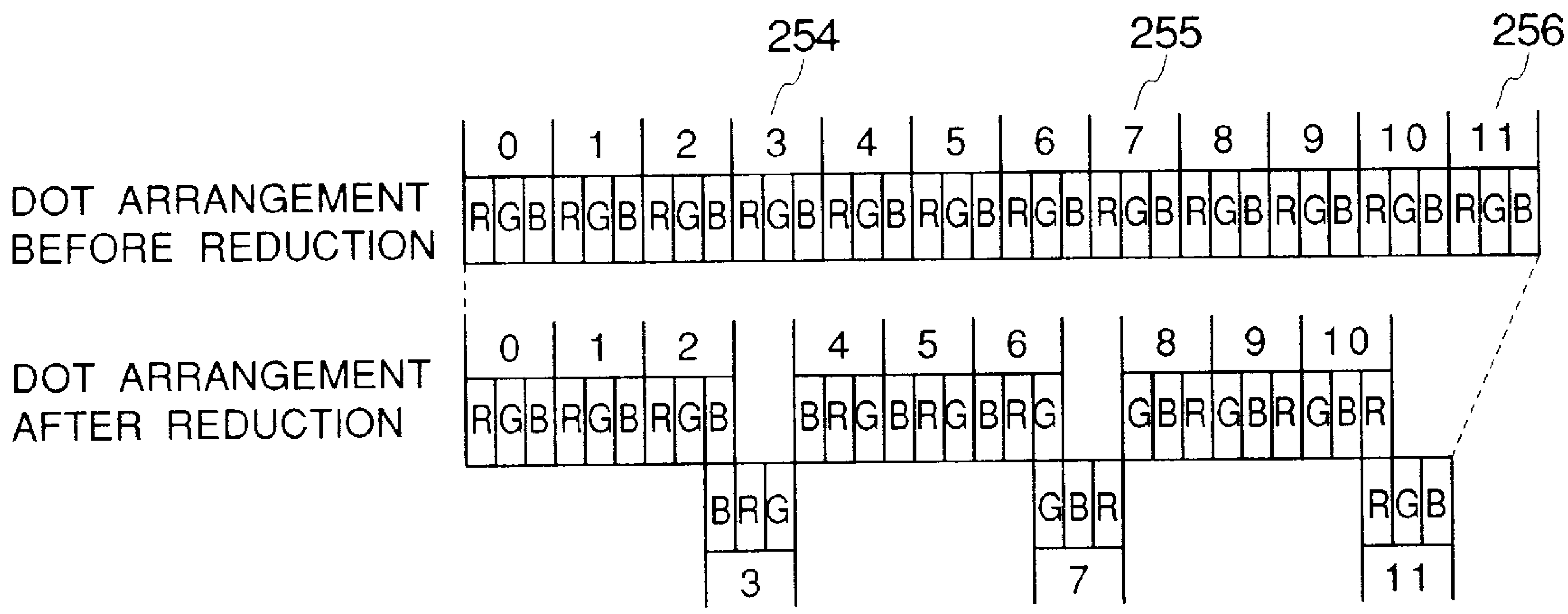

254
255
256
DOT ARRANGEMENT BEFORE REDUCTION
DOT ARRANGEMENT AFTER REDUCTION

FIG.31

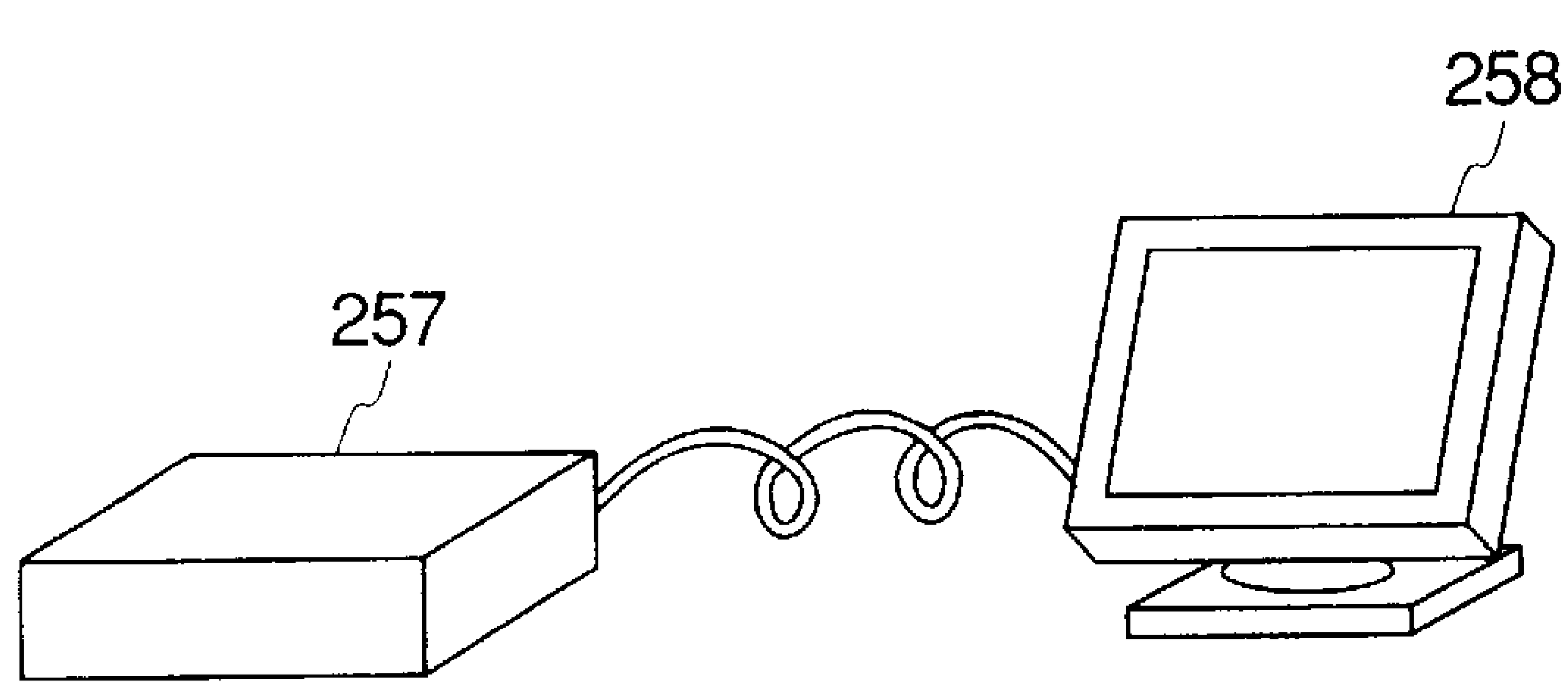
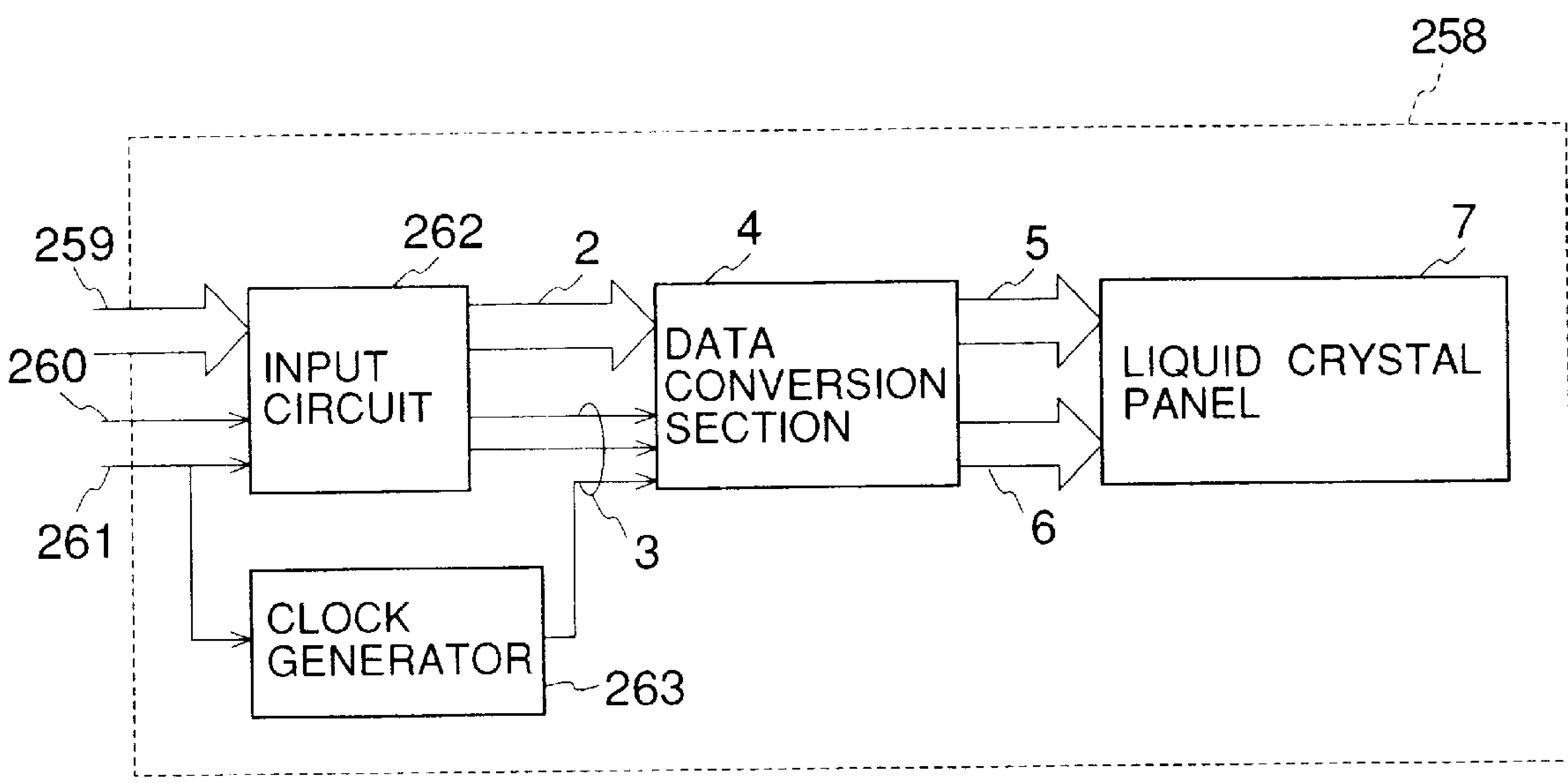

257
258

FIG.32



258
259
260
261
262
2
4
5
7
6
3
263
INPUT CIRCUIT
DATA CONVERSION SECTION
LIQUID CRYSTAL PANEL
CLOCK GENERATOR

LIQUID CRYSTAL DISPLAY SYSTEM CAPABLE OF REDUCING AND ENLARGING RESOLUTION OF INPUT DISPLAY DATA

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a display system for use when display data output by a computer differs in resolution from that of a liquid crystal display screen which is to display the display data is used as a display for a personal computer, etc.

2. Description of the Related Art

A conventional liquid crystal display receives an interface signal containing display data and a timing signal output by a computer, converts the interface signal into a drive signal for the liquid crystal display, and feeds the drive signal into a liquid crystal drive means. The liquid crystal drive means converts the display data contained in the drive signal into a liquid crystal drive voltage corresponding to the display data and outputs the voltage to a liquid crystal panel. When receiving the liquid crystal drive voltage, the liquid crystal panel displays an image. If the input interface signal differs from the liquid crystal panel in resolution, for example, if the resolution of the input interface signal is larger than that of the liquid crystal panel, a part of the display data contained in the input interface signal is deleted to match the resolution of the interface signal with that of the liquid crystal panel, as described in Japanese Patent Laid-Open No. 57-115593. In the conventional example, the display object is limited to characters and space dots around a character are deleted for each kind of character. The part to be deleted needs to be specified for each kind of character.

The conventional example applies to characters and is not intended for displaying data other than characters.

SUMMARY OF THE INVENTION

It is therefore an object of the invention to provide a liquid crystal display system which can accept an interface signal having a resolution different from that of the liquid crystal display for displaying the display data contained in the interface signal regardless of the type of display data.

To this end, according to one aspect of the invention, there is provided a method of converting first display data in a raster scan format having a first resolution received from an external system into second display data for a liquid crystal display having a second resolution different from the first resolution, the method comprising the steps of:

a) generating data for n vertical or horizontal lines based on specific m vertical or horizontal lines contiguous to each other of the first display data, where m is an integer of two or greater and n is an integer less than m;

b) repeating at least one of the following steps c) and d) as many times as required in sequence at different positions on a screen of the liquid crystal display;

c) replacing k ($n<k\leqq m$) lines of the m vertical or horizontal lines with the n vertical or horizontal lines; and

d) adding the n vertical or horizontal lines to the m vertical or horizontal lines.

The data conversion means converts display data received from a personal computer or the like into display data using gray scale data so that it matches the resolution of the liquid crystal display. Thus, even display data output by the personal computer or the like assuming an output device having resolution different from that of the liquid crystal display can be displayed on the liquid crystal display.

According to another aspect of the invention, there is provided a method of converting first display data in a raster scan format having a first horizontal resolution received from an external system into second display data for a liquid crystal display having a second horizontal resolution smaller than the first horizontal resolution, the method comprising the steps of:

a) virtually dividing a set of M contiguous dots on a horizontal line into N equal partitions, where M is an integer of three or greater and N is an integer of two or more, less than M;

b) repeating, N times with respect to the N equal partitions, a weighted addition of data values of dots contained in one partition, depending upon what percentage of the partition is occupied by each dot in the partition;

c) replacing the M dots with n dots which have the data values of the N partitions resulting from the weighted additions in step b);

d) repeating steps a) to c) for different sets of M contiguous dots in sequence at least in a part of one horizontal line; and

e) repeating step d) for different horizontal lines in sequence.

According to still another aspect of the invention, there is provided a method of converting first display data in a raster scan format having first horizontal resolution received from an external system into second display data for a liquid crystal display having second horizontal resolution larger than the first horizontal resolution, the method comprising the steps of:

a) virtually dividing a set of M contiguous dots on a horizontal line into N equal partitions, where M is an integer of two or greater and N is an integer of three or more which is greater than M;

b) repeating, N times with respect to the N equal partitions, a weighted addition of one or more data values of dots contained in one partition, depending upon what percentage of each dot contributes in the partition;

c) replacing the M dots with N dots which have the data values of the N partitions resulting from the weighted additions in step b);

d) repeating steps a) to c) for different sets of M contiguous dots in sequence at least in a part of one horizontal line; and

e) repeating step d) for different horizontal lines in sequence.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. **1** is a block diagram of a system to which the invention is applied;

FIG. **2** is an illustration showing resolutions to which the invention may be applied;

FIG. **3** is an illustration of reduction and enlargement by gray scale line replacement and insertion according to the invention;

FIG. **4** is an illustration of a method for detecting an area with less display data;

FIGS. **5A** and **5B** are illustrations of gray scale pixel calculation methods;

FIG. **6** is an illustration of replacement with a gray scale line using three extraction lines;

FIG. **7** is a block diagram showing the configuration of the data conversion section shown in FIG. **1**;

FIG. **8** is a block diagram showing the configuration of a reduction process section shown in FIG. **11**;

FIG. **9** is a block diagram of a DAD conversion system;

FIG. **10** is an illustration of DAD conversion operation of the system shown in FIG. **9**;

FIG. **11** is a block diagram showing the configuration of the R data converter shown in FIG. **7**;

FIG. **12** is a block diagram showing the configuration of the enlargement process section shown in FIG. **11**;

FIG. **13** is an input/output timing chart for a lateral reduction process;

FIG. **14** is an input/output timing chart for a longitudinal reduction process;

FIG. **15** is an input/output timing chart for a lateral enlargement process;

FIG. **16** is an input/output timing chart for a longitudinal enlargement process;

FIG. **17** is a drawing representing the concept of lateral reduction in another embodiment of the invention;

FIG. **18** is an illustration of reduction by gray scale replacement related to FIG. **17**;

FIG. **19** is a drawing representing the concept of lateral enlargement in another embodiment of the invention;

FIG. **20** is an illustration of enlargement by gray scale insertion related to FIG. **19**;

FIG. **21** is an illustration of a method for detecting a line with less display data;

FIG. **22** is a block diagram showing the configuration of a data conversion section in another embodiment of the invention;

FIG. **23** is a block diagram showing the configuration of the R data converter shown in FIG. **22**;

FIG. **24** is a block diagram showing the configuration of the reduction process section shown in FIG. **23**;

FIG. **25** is a block diagram showing the configuration of the enlargement process section shown in FIG. **23**;

FIG. **26** is an input/output timing chart for the lateral enlargement process;

FIG. **27** is an input/output timing chart for the lateral reduction process;

FIG. **28** is an input/output timing chart for the longitudinal reduction process;

FIG. **29** is an input/output timing chart for the longitudinal enlargement process;

FIG. **30** is a conceptual diagram of the reduction process executed in dot units;

FIG. **31** is a conceptual illustration of a system to which the invention is applied; and

FIG. **32** is a block diagram showing a liquid crystal display unit to which the invention is applied.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the invention will now be described with reference to the accompanying drawings.

A first embodiment of a personal computer system to which a liquid crystal display system of the invention is connected will be discussed with reference to **4**, **5A–5B**, and **6** to FIGS. **1** to **16**.

FIG. **1** is a block diagram of a personal computer system to which the invention is applied. In the figure, numeral **1** indicates a personal computer or workstation (PC) which contains a central processing unit (CPU) **101**, etc., numeral **2** indicates display data, numeral **3** indicates a timing signal, numeral **4** indicates a data conversion section for converting display data of the PC **1** into a liquid crystal display signal, numeral **5** indicates liquid crystal display data, numeral **6** indicates a liquid crystal display timing signal, and numeral **7** indicates a liquid crystal panel. The data conversion section **4** and the liquid crystal panel **7** make up a liquid crystal display unit. The data conversion section **4** converts the display data **2** input from the PC **1** into the liquid crystal display data **5** enlarged or reduced in accordance with the resolution of the liquid crystal panel **7** and generates the liquid crystal display timing signal **6**. The liquid crystal display data **5** and the liquid crystal display timing signal **6** are collectively called a drive signal. The display data is converted into a liquid crystal drive voltage at the liquid crystal panel **7**. In the description to follow, assume that the display data **2** has 4-bit gradation data for each of the primary colors red (R), green (G), and blue (B) and is transferred in series in synchronization with the timing signal **3**. For simplicity, assume that the liquid crystal panel **7** consists of pixels of 1024×768 dots and that the PC **1** outputs timing signal and display data of 1120×780 dots, which will be hereinafter referred to as display mode **1** throughout the specification, or 640×480 dots, which will be hereinafter referred to as display mode **2** throughout the specification, in response to the display mode.

FIG. **2** shows the display modes of the invention. The data conversion section **4** discriminates between the display modes **1** and **2** and executes reduction processes in display mode **1** and enlargement processes in display mode **2** in response to the display mode.

Also, assume that the number of colors that can be displayed on the liquid crystal panel **7** is 4096 and that the PC **1** performs so-called raster scanning in which with each pixel represented by 4-bit attribute data (gradation data) for each of R (red), G (green), and B (blue), the data is output for one pixel at a time in sequence from left to right in the horizontal line direction and the operation is repeated in sequence as many times as the number of the horizontal lines from top to bottom.

Some operation examples of the data conversion section **4** will be discussed in the first embodiment.

As the first operation example, a gray scale line replacement/insertion system will be described with reference to FIG. **3**.

FIG. **3** shows gray scale line replacement in display mode **1** and insertion in display mode **2**, wherein numerals **8** and **9** indicate first and second horizontal extraction lines representing horizontal replacement or insertion positions, numerals **10** and **11** indicate first and second vertical extraction lines representing vertical replacement or insertion positions, numeral **12** indicates a horizontal gray scale line resulting from calculating the gray scale for the first and second horizontal extraction lines **8** and **9**, and numeral **13** indicates a vertical gray scale line resulting from calculating the gray scale for the first and second vertical extraction lines **10** and **11**. In display mode **1**, horizontal and vertical gray scale lines are prepared from first and second horizontal and vertical extraction lines and the first and second horizontal extraction lines **8** and **9** are replaced with the horizontal gray scale line **12** and the first and second vertical extraction lines **10** and **11** are replaced with the vertical gray scale line **13**, thereby performing reduction processing. In display mode **2**, a horizontal gray scale line is inserted between the horizontal extraction lines **8** and **9** and a vertical gray scale line is inserted between the vertical extraction lines **10** and **11**, thereby performing enlargement processing.

The extraction line positions may be equally spaced as desired, or lines with less display data may be found and selected to be extraction lines.

FIG. **4** shows a method of determining the position of a horizontal or vertical extraction line where replacement or insertion is to be made from the display data amount. In the figure, numeral **14** indicates the summation result of the number of pixels displayed in a color different from the background color for each vertical line, numeral **15** indicates the summation result of the number of pixels displayed in a color different from the background color for each horizontal line, and numeral **16** indicates a hatched area containing the positions of horizontal or vertical lines where insertion or deletion can be made, determined from the summation results **14** and **15**. In the example, positions having the smallest amount of display data possible are found for replacement or insertion positions.

Further, for a screen with windows displayed, an area outside the window regions may be detected for replacement or insertion positions.

FIGS. **5**A and **5**B show a gray scale pixel calculation method.

For example, to prepare a gray scale pixel from two pixels shown in FIG. **5**A, the average values of the attributes for R, G, and B may be calculated:

$$R' = (R0 + R1)/2 \qquad \text{Expression1}$$
$$G' = (G0 + G1)/2$$
$$B' = (B0 + B1)/2$$

This calculation can be repeated as many times as the number of pixels making up one line for calculating a gray scale line. Further, to calculate the gray scale from a number of pixels as shown in FIG. **5**B, such as at the intersection of horizontal and vertical lines, the average of the attributes for the four pixels

$$R' = (R0 + R1 + R2 + R3)/4 \qquad \text{Expression2}$$
$$G' = (G0 + G1 + G2 + G3)/4$$
$$B' = (B0 + B1 + B2 + B3)/4$$

may be used as gray scale pixel data.

When the average values are calculated, fractional digits may occur. It is desirable to handle the fractional digits so that a color different from the background color is output in response to the attribute of the background color. For example, if the background is black (R=0000, G=0000, B=0000), when the average values of R, G, and B are calculated, fractions are rounded up or rounded off, and if the background is white (R=1111, G=1111, B=1111), fractions are rounded down, whereby a color different from the background color can be displayed. If the background color has different attributes for R, G, and B, such as blue (R=0000, G=0000, B=1111), fractions are rounded up when gradation of R or G is calculated, or fractions are rounded down when gradation of B is calculated.

Further, another system in which the number of extraction lines in the reduction process is three will be discussed with reference to FIG. **6**. Here, the processing is described by taking only horizontal lines as an example and similar processing is also performed for the vertical lines.

In FIG. **6**, numerals **17**, **18**, and **19** indicate first, second, and third extraction lines and numeral **20** indicates a gray scale line found from the average of the display data for the three lines. The second extraction line **18** is replaced with the gray scale data line **20** and the third extraction line **19** is deleted, thereby performing the reduction process. Since similar processing is also performed in the vertical direction, the average of 9-pixel display data may be calculated for the intersection of the extraction lines.

The way to find the gray scale data is similar to that in the first operation example.

Next, an example of the hardware configuration of the data conversion section **4** for carrying out the first operation example will be discussed with reference to FIGS. **7** and **8**.

FIG. **7** is an example of the configuration of the data conversion section **4**, wherein numerals **21**, **22**, and **23** indicate R display data, G display data, and B display data of the display data **2** respectively, numeral **24** indicates an R data converter, numeral **25** indicates a G data converter, numeral **26** indicates a B data converter, numeral **27** indicates B liquid crystal display data, numeral **28** indicates G liquid crystal display data, numeral **29** indicates R liquid crystal display data, numeral **51** indicates a display mode determination section, numeral **52** indicates a display mode signal, numeral **30** indicates a liquid crystal display timing signal generator, and numeral **6** indicates a liquid crystal display timing signal. The display mode determination section **51** determines the display mode from the timing signal **3** and outputs the display mode signal **52**. The data converters **24**, **25**, and **26** process the R, G, and B display data **21**, **22**, and **23** respectively in accordance with the resolution represented by the display mode signal **52**. The liquid crystal display timing signal generator **30** generates the liquid crystal display timing signal **6** matched with the output resolution represented by the display mode signal **52** from the timing signal **3**.

FIG. **11** is an example of the configuration of the R data converter **24**. The G and B data converters **25** and **26** also each have the same configuration as the R data converter **24**. In FIG. **11**, numeral **53** indicates a reduction process section, numeral **54** indicates an enlargement process section, numeral **55** indicates reduced display data, numeral **56** indicates enlarged display data, and numeral **57** indicates resolution switch means. When the display mode signal **52** represents the display mode **1**, the reduction process section **53** converts the R display data **21** into the reduced display data **55**; at that time, the enlargement process section **54** does not operate. When the display mode signal **52** represents the display mode **2**, the enlargement process section **54** converts the R display data **21** into the enlarged display data **56**; at that time, the reduction process section **53** does not operate. The resolution switch means **57** is responsive to the display mode signal **52** for outputting the reduced display data **55** when the display mode signal **52** represents the display mode **1** or the enlarged display data **56** when the display mode signal **52** represents the display mode **2** as the R liquid crystal display data **29**. Although the reduction process section **53** and the enlargement process section **54** are provided to support two display modes in the embodiment, additional reduction or enlargement process sections can also be provided for supporting other resolutions.

FIG. **8** is one example of the configuration of the reduction process section **53**. Hereinafter, a horizontal row of dots of display data will be referred to as a line. This means that the liquid crystal panel **7** used in the invention consists of 1024 dots×768 lines.

In FIG. **8**, numeral **32** indicates a latch, numeral **33** indicates preceding dot data, numeral **34** indicates a horizontal operation section, numeral **35** indicates horizontal gray scale data, numeral **36** indicates a horizontal selector, numeral **37** indicates horizontal data, numeral **38** indicates a line memory, numeral **39** indicates a vertical selector, numeral **40** indicates preceding line data, numeral **41** indicates operational horizontal data, numeral **42** indicates a vertical operation section, numeral **43** indicates vertical gray scale data, numeral **44** indicates output horizontal data, and numeral **45** indicates an output selector. The latch **32**, which latches the R display data **21** in synchronization with a dot clock (not shown) provided by the timing signal **3**, outputs the preceding dot data **33** which is display data one dot before the R display data **21**. The horizontal operation section **34** performs an operation on the preceding dot data **33** and the R display data **21** (averaging them) and outputs the horizontal gray scale data **35**. The horizontal selector **36** selects either the horizontal gray scale data **35** or the R display data **21** depending on which position of the liquid crystal panel **7** the R display data **21** is at, and outputs the data **35** or **21** as the horizontal data **37**, as described below in detail.

The line memory **38** stores one line of the horizontal data **37** and outputs it as the preceding line data **40** which is data one line before when the display data of the next line is input. The vertical selector **39** outputs the horizontal data **37** to either the vertical operation section **42** as the operational horizontal data **41** or the output selector **45** as the output horizontal data **44** depending on which position of the liquid crystal panel **7** the horizontal data **37** is at, as described below in detail. The vertical operation section **42** performs an operation on the preceding line data **40** and the operational horizontal data **41** and outputs the result as the vertical gray scale data **43**. The output selector **45** outputs either the vertical gray scale data **43** or the output horizontal data **44** depending on which position of the liquid crystal panel **7** the R display data **21** is at, as with the R liquid crystal display data **29**, as described below in detail.

FIG. **12** is an example of the configuration of the enlargement process section **54**, wherein numeral **58** indicates a gray scale data frame memory, numeral **59** indicates a display data frame memory, numeral **60** indicates gray scale read data, and numeral **61** indicates display read data. Other components identical with those of the reduction process section **53** previously described with reference to FIG. **8** are denoted by the same reference numerals in FIG. **12**. In FIG. **12**, a latch **32** and a horizontal operation section **34** operate like those of the reduction process section **53**. If R display data **21** is data on a first vertical extraction line, a horizontal selector **36** outputs the R display data **21**, then outputs gray scale horizontal data **35** for inserting a vertical line before R display data **21** for the next dot comes. A line memory **38**, a vertical selector **39**, and a vertical operation section **42** operate like those of the reduction process section **53**. Vertical gray scale data **43** for one screen (frame) is stored in the gray scale data frame memory **58** and output horizontal data **44** for one screen (frame) is stored in the display data frame memory **59**. When display data of the next screen (frame) is input, the vertical gray scale read data **60** is read and inserted into any position between the display read data **61** for inserting a horizontal line.

Next, the operation related to the reduction process by gray scale replacement will be discussed in detail with reference to FIGS. **1**, **7**, **8**, and **11**.

In FIG. **1**, the data conversion section **4** converts the display data **2** and the timing signal **3** into the liquid display data **5** and the liquid crystal display timing signal **6** matched with the liquid crystal panel **7** for output. In FIG. **7**, the display mode determination section **51** determines the display mode from the timing signal **3** and the display mode signal **52** matched with the resolution of the liquid crystal panel **7** for display. The display mode can be determined by counting the number of clocks of the timing signal **3** or by feeding the display mode signal **52** from an external system without providing the display mode determination section **51**. X, G, and B of the display data **2** are input to the R, G, and B data converters **24**, **25**, and **26** respectively, which then convert the data into the liquid crystal display data **5** matched with the display mode represented by the display mode signal **52**. The liquid crystal display timing signal generator **30** generates the liquid crystal display timing signal **6** matched with the display mode represented by the display mode signal **52** from the timing signal **3**.

The operation of the R data converter **24** for display data conversion will be discussed in detail with reference to FIG. **11**. Each of the G and B data converters **25** and **26** performs an operation similar to that of the R data converter **24**.

In FIG. **11**, when the display mode signal **52** represents the display mode **1**, the reduction process section **53** operates and generates the reduced display data **55**. When the display mode signal **52** represents the display mode **2**, the enlargement process section **54** operates and generates the enlarged display data **56**. The resolution switch means **57** is responsive to the display mode signal **52** for selecting and outputting the reduced display data **55** in the display mode **1** or the enlarged display data **56** in the display mode **2**. As described above, additional reduction and enlargement process sections can be provided to make up a data conversion section which supports other resolutions.

The operation of the reduction process section **53** will be discussed in detail with reference to FIGS. **8**, **13**, and **14**. In FIG. **8**, since the latch **32** latches input R display data **21** according to a dot clock, the data output by the latch **32** becomes the preceding dot display data **33** which is the data one dot before the R display data **21**. The horizontal operation section **34** performs an operation on the preceding dot display data **33** and the R display data **21** to generate gray scale data, and outputs it as the horizontal gray scale data **35**. If the R display data **21** is data on a first vertical extraction line, the horizontal selector **36** outputs neither the horizontal gray scale data **35** nor the R display data **21**; if it is data on a second vertical extraction line, the horizontal selector **36** outputs the horizontal gray scale data **35**; if it is not data on the first or second vertical extraction line, the horizontal selector **36** outputs the R display data **21** as the horizontal data **37**.

The horizontal data **37** for one line is stored in the line memory **38**, and is read out when horizontal data **37** for the next line is input. Therefore, the data output by the line memory **38** becomes the preceding line display data **40** which is one line before the horizontal data **37**. If the horizontal data **37** is data on a first horizontal extraction line, the vertical selector **39** does not output the data to the vertical operation section **42** or the output selector **45**; if it is data on a second horizontal extraction line, the vertical selector **39** outputs the data to the vertical operation section **42** as the operational horizontal data **41**; if it is not data on the first or second vertical extraction line, the vertical selector **39** outputs the data to the output selector **45** as the output horizontal data **44**. The vertical operation section **42** performs an operation on the preceding line display data **40** and the operational horizontal data **41** to generate gray scale data, and outputs it as the vertical gray scale data **43**. If the horizontal data **37** is data on the first horizontal extraction line, the output selector **45** outputs neither the vertical gray scale data **43** nor the output horizontal data **44**; if it is data on the second horizontal extraction line, the output selector **45** outputs the vertical gray scale data **43**; if it is not data on the first or second horizontal extraction line, the output selector **45** outputs the output horizontal data **44**. The reduction process by gray scale replacement shown in FIG. **3** is now complete.

FIG. **13** is an input/output timing chart for the lateral reduction process in the reduction process section **53**.

In the figure, numeral **101** indicates the input timing of the R display data **21**, numeral **102** indicates the output timing for the preceding dot data **33**, and numeral **103** indicates the output timing for the horizontal gray scale data **35**, showing that the result of dividing the sum of the R display data **21** and the preceding dot data **33** by two is output as the horizontal gray scale data **35**. Numeral **104** indicates the select signal timing of the horizontal selector **36** and numeral **105** indicates the output timing of horizontal data **37**, showing that the select signal **104** is set to 1 at the position next to the first vertical extraction line **10** shown in FIG. **3**, outputting the horizontal gray scale data **35**. Numeral **106** indicates the timing of a synchronous clock contained in the liquid crystal timing signal **6** and numeral **107** indicates the timing of data displayed on the liquid crystal panel **7**. X2 data is deleted by synchronizing the horizontal data timing **105** with the synchronous clock timing **106** for stopping the clock finally corresponding to the position of the first vertical extraction line **10**.

FIG. **14** is an input/output timing chart for the longitudinal reduction process of the reduction process section **53**.

In the figure, numeral **108** indicates the line output timing for the horizontal data **37**, numeral **109** indicates the output timing for the preceding line signal **40** output by the line memory **38**, numeral **110** indicates the output timing for the vertical gray scale data **43** generated by performing an operation on the output of the line memory **38** and the horizontal data **37**, and numeral **112** indicates the output timing of the reduced display signal **55** output from the output selector **45**. L**0** and L**1** denote data for the first line and data for the second line respectively; L**0** and L**1** are averaged to generate the vertical gray scale data **43**. This also applies to the second line, third line, and later. Numeral **111** indicates a select signal for the output selector **45**, which allows the vertical gray scale data **43** to be output on the line next to the first horizontal extraction line **8** shown in FIG. **3**. Numeral **112** indicates the output timing of the reduced display signal **55**, numeral **113** indicates the output timing of a horizontal synchronizing signal contained in the liquid crystal display timing signal **6**, and numeral **114** indicates the timing of display data actually displayed. Although the output timing **112** of the output selector **45** follows the select signal timing **111**, L**1** is not displayed as shown in **114** because the actual horizontal synchronizing signal is as shown in **113**.

Next, the enlargement process by gray scale insertion will be discussed in detail with reference to FIGS. **12**, **15**, and **16**.

In FIG. **12**, the latch **32** and the horizontal operation section **34** operate like those of the reduction process section **53**. If R display data **21** is data on a first vertical extraction line, the horizontal selector **36** outputs the R display data **21**, then outputs gray scale horizontal data **35** for inserting a vertical line before R display data **21** for the next dot comes. The line memory **38**, the vertical selector **39**, and the vertical operation section **42** operate like those of the reduction process section **53**. Vertical gray scale data **43** for one screen (frame) is stored in the gray scale data frame memory **58** and output horizontal data **44** for one screen (frame) is stored in the display data frame memory **59**. When display data for the next screen (frame) is input, the vertical gray scale read data **60** is read and inserted into any position between the display read data **61** for inserting a horizontal line.

FIG. **15** is an input/output timing chart of the lateral enlargement process for the enlargement process section **54**.

In the figure, numeral **115** indicates the input timing for the R display data **21**, numeral **116** indicates the output timing for the preceding dot data **33**, and numeral **117** indicates the output timing for the horizontal gray scale data **35**, showing that the result of dividing the sum of the R display data **21** and the preceding dot data **33** by two is output as the horizontal gray scale data **35**. Numeral **118** indicates the select signal timing for the horizontal selector **36**, numeral **119** indicates the output timing for the horizontal data **37**, and numeral **120** indicates the timing of a synchronous clock contained in the liquid crystal display timing signal **6**, showing that the select signal **104** is set to 1 at the position next to the first vertical extraction line **10** shown in FIG. **3**, outputting the horizontal gray scale data **35**. The period of only the synchronous clock at the time is doubled and while 1-dot data is input, 2-dot data of the horizontal gray scale data **35** and the R display data **21** is output.

FIG. **16** is an input/output timing chart of the longitudinal enlargement process for the enlargement process section **54**.

In the figure, numeral **1119** indicates the output timing for the horizontal data **37** for each line, numeral **1120** indicates the output timing for the preceding line data **40** for each line output from the line memory **38**, and numeral **121** indicates the output timing of vertical gray scale data **43** for each line, showing that the vertical gray scale data **43** is the result of dividing by two the sum of the horizontal data **37** and the preceding line data **40** which is the data one line before the horizontal data **37**. Numeral **122** indicates a timing signal representing the position into which the vertical gray scale data **43** is inserted, numeral **123** indicates a horizontal synchronizing signal contained in the liquid crystal display timing signal **6**, and numeral **124** indicates the timing for each line actually displayed. When the vertical gray scale data is inserted, the vertical gray scale data insertion timing **122** is set to "1" on the line next to the first horizontal extraction line **8**. At this time, the period of the synchronous clock is doubled and while 1-line data is input, 2-line data is output. For the first one of these two lines, the vertical gray scale data is selectively output from the gray scale data frame memory **58** and for the second line, the horizontal data is selectively output from the display data frame memory **59**.

When a number of insertion lines are equally spaced, for example, when a gray scale data line is to be inserted every n lines, (n+1) line memories are provided for storing gray scale data to be inserted and line data. When the next data is input, the (n+1)-line data containing the gray scale line data is read out while n-line data is stored, whereby a horizontal line can be inserted without providing the frame memories.

The data conversion section **4** which performs the processing may be software which uses the CPU **101**, hardware, may exist in the PC **1**, or may be contained in the liquid crystal panel **7**.

As the second operation example of the data conversion section **4**, a system of converting horizontal resolution with low-pass filters will be described with reference to FIG. **9**.

FIG. **9** shows the configuration of an R data converter **24** with a low-pass filter, wherein numeral **46** is a D/A converter, numeral **47** indicates analog R display data, numeral **48** indicates a low-pass filter, numeral **49** indicates smoothed R display data, numeral **50** indicates an A/D converter, and numeral **51** indicates a display mode determination section which performs the same operation as that described above. The D/A converter **46** immediately converts digital output R display data **21** into analog R display data **47** and outputs the analog R display data **47** to the low-pass filter **48** which then smooths the data **47** to generate the smoothed R display data **49**. Lastly, the smoothed R display data is restored to a digital signal by the A/D converter **50** using the liquid crystal display timing signal **6** matched with the resolution of the liquid crystal display. If the liquid crystal display timing signal **6** has a higher frequency than the input timing signal **3**, the enlargement process is executed; if the former has lower frequency than the latter, the reduction process is executed.

FIG. **10** shows a signal conversion example of display data in the enlargement process.

Since the liquid crystal display timing signal **6** having higher frequency than the input timing signal **3** is used, enlarged R liquid crystal display data **29** is generated.

We have discussed the enlargement/reduction techniques as execution of the enlargement or reduction process so that the display data output from the PC **1** is made the same as the liquid crystal panel in resolution directly, but a technique which employs step-by-step execution of the enlargement or reduction process may be used. For example, to convert display data represented by 640×480 dots into 1120×780 dots, first the display data is first enlarged to 1280×960 dots, which is twice 640×480 dots, then the enlarged displayed data is reduced to 1120×780 dots. If an attempt is made to enlarge the display data directly to 1120×780 dots, it takes time because of a large number of insertion lines. However, it does not take much time to enlarge the display data to 1280×960 equivalent to a double of 640×480 dots because of simple processing, and then only a few lines need to be removed. Therefore, the entire processing can be performed at high speed.

In contrast, if the resolution of the liquid crystal panel **7** in FIG. **1** is 640×480 dots and display data of 1120×780 dots is output from the PC **1**, the enlargement process can be simply the reverse of the reduction process, which makes the processing fast.

In the invention, how the resolution should be adjusted can be determined automatically by providing means for determining what resolution the display data supplied to the liquid crystal display has, such as means for determining resolution from the timing signal input from the computer.

Another embodiment of a personal computer system to which a liquid crystal display system of the invention is connected will be discussed with reference to FIGS. **17** to **30**.

The system configuration of another embodiment is the same as that shown in FIG. **1** except for the data conversion section **4**.

Some operation examples of the data conversion section **4** will be discussed in another embodiment.

As the first operation example, a gradation integration/reduction system will be described with reference to FIG. **17**.

FIG. **17** shows the concept of the lateral reduction method in display mode **1** (1120×780 dots). Here, the reduction of five pixels to four pixels is discussed, and FIG. **17** represents R, G, or B color data.

In FIG. **17**, numeral **8** indicates 5-pixel display data and numeral **9** indicates 4-pixel display data after reduction. The vertical axis is entered with 1 as the highest intensity and 0 as the lowest intensity and the horizontal axis is entered as pixel positions. To reduce the 5-pixel data **8** to the 4-pixel data **9**, the 5-pixel width is virtually quartered, namely, the 1-pixel width is widened one-quarter and display data of five-quarter pixel width is converted into display data of 1-pixel width. Therefore, the calculation expression for the 1-pixel display data is

$$X(0,0)'=(X(0,0)\times 4+X(0,1)\times 1)/5 \qquad \text{Expression3}$$
$$X(0,1)'=(X(0,1)\times 3+X(0,2)\times 2)/5$$
$$X(0,2)'=(X(0,2)\times 2+X(0,3)\times 3)/5$$
$$X(0,3)'=(X(0,3)\times 1+X(0,4)\times 4)/5$$

where X (0, 0) to X (0, 4) are gray scale data for the first to fifth pixels before reduction and X (0, 0)' to X (0, 3)' are gray scale data for the first to fourth pixels after reduction, wherein the first digit represents the line number and the second digit represents the pixel number. That is, X (0, 0) is gray scale data for the first pixel of the first line and that X (0, 1) is gray scale data for the second pixel of the first line. Since the description assumes that 1120 pixels are reduced to 1024 pixels, 35 pixels are reduced to 32 pixels from 1024/1120=32/35. The calculation expression is:

$$X(0,0)'=(X(0,0)\times 32+X(0,1)\times 3)/35 \qquad \text{Expression4}$$
$$X(0,1)'=(X(0,1)\times 29+X(0,2)\times 6)/35$$
$$X(0,2)'=(X(0,2)\times 26+X(0,3)\times 9)/35$$
$$X(0,3)'=(X(0,3)\times 23+X(0,4)\times 12)/35$$
$$X(0,4)'=(X(0,4)\times 20+X(0,5)\times 15)/35$$
$$X(0,5)'=(X(0,5)\times 17+X(0,6)\times 18)/35$$
$$X(0,6)'=(X(0,6)\times 14+X(0,7)\times 21)/35$$
$$X(0,7)'=(X(0,7)\times 11+X(0,8)\times 24)/35$$
$$X(0,8)'=(X(0,8)\times 8+X(0,9)\times 27)/35$$
$$X(0,9)'=(X(0,9)\times 5+X(0,10)\times 30)/35$$
$$X(0,10)'=(X(0,10)\times 2+X(0,11)\times 32+X(0,12)\times 1)/35$$
$$X(0,11)'=(X(0,12)\times 31+X(0,13)\times 4)/35$$
$$X(0,12)'=(X(0,13)\times 28+X(0,14)\times 7)/35$$
$$X(0,13)'=(X(0,14)\times 25+X(0,15)\times 10)/35$$
$$X(0,14)'=(X(0,15)\times 22+X(0,16)\times 13)/35$$
$$X(0,15)'=(X(0,16)\times 19+X(0,17)\times 16)/35$$
$$X(0,16)'=(X(0,17)\times 16+X(0,18)\times 19)/35$$
$$X(0,17)'=(X(0,18)\times 13+X(0,19)\times 22)/35$$
$$X(0,18)'=(X(0,19)\times 10+X(0,20)\times 25)/35$$
$$X(0,19)'=(X(0,20)\times 7+X(0,21)\times 28)/35$$
$$X(0,20)'=(X(0,21)\times 4+X(0,22)\times 31)/35$$
$$X(0,21)'=(X(0,22)\times 1+X(0,23)\times 32+X(0,24)\times 2)/35$$
$$X(0,22)'=(X(0,24)\times 30+X(0,25)\times 5)/35$$
$$X(0,23)'=(X(0,25)\times 27+X(0,26)\times 8)/35$$
$$X(0,24)'=(X(0,26)\times 24+X(0,27)\times 11)/35$$
$$X(0,25)'=(X(0,27)\times 21+X(0,28)\times 14)/35$$
$$X(0,26)'=(X(0,28)\times 18+X(0,29)\times 17)/35$$

-continued

$$X(0,27)'=(X(0,29)\times 15+X(0,30)\times 20)/35$$

$$X(0,28)'=(X(0,30)\times 12+X(0,31)\times 23)/35$$

$$X(0,29)'=(X(0,31)\times 9+X(0,32)\times 26)/35$$

$$X(0,30)'=(X(0,32)\times 6+X(0,33)\times 29)/35$$

$$X(0,31)'=(X(0,32)\times 3+X(0,34)\times 32)/35$$

where X (0, 0) to X (0, 34) are gray scale data for the first to 35th pixels before reduction and X (0, 0)' to X (0, 31)' are gray scale data of the first to 32nd pixels after reduction. Similar operations can also be performed in the longitudinal direction. However, to use a similar method for longitudinal processing, a memory for a plurality of lines would be required, which would increase the size of the circuit. Thus, the following processing can also be carried out so as not to increase the circuit scale:

FIG. **18** shows reduction by gray scale replacement wherein a longitudinal reduction method is also shown.

To reduce 780 lines to 768 lines in the longitudinal direction, the deletion of 12 lines is required. In FIG. **18**, numeral **210** indicates an extraction line to be deleted and numeral **211** indicates a replacement line after reduction. Longitudinal reduction is executed by replacing the extraction line **210** and the following line with the replacement line **211** which is the gray scale of the extraction line **210** and the following line. Therefore, pixels, other than the replacement line **211**, to which "'" is attached are pixels reduced using Expression 4 in the lateral direction, and to process the extraction line **210** and the following line using Expression 4 and average these two lines, the replacement line **211** is

Expression5

$$X(2,0)'=(X(2,0)\times 32+X(3,0)\times 32+X(2,1)\times 3+X(3,1)\times 3)/70$$

$$X(2,1)'=(X(2,1)\times 29+X(3,1)\times 29+X(2,2)\times 6+X(3,2)\times 6)/70$$

$$X(2,2)'=(X(2,2)\times 26+X(3,2)\times 26+X(2,3)\times 9+X(3,3)\times 9)/70$$

$$X(2,3)'=(X(2,3)\times 23+X(3,3)\times 23+X(2,4)\times 12+X(3,4)\times 12)/70$$

$$X(2,4)'=(X(2,4)\times 20+X(3,4)\times 20+X(2,5)\times 15+X(3,5)\times 15)/70$$

$$X(2,5)'=(X(2,5)\times 17+X(3,5)\times 17+X(2,6)\times 18+X(3,6)\times 18)/70$$

$$\vdots$$

$$X(2,26)'=(X(2,28)\times 18+X(3,28)\times 18+X(2,29)\times 17+X(3,29)\times 17)/70$$

$$X(2,27)'=(X(2,29)\times 15+X(3,29)\times 15+X(2,30)\times 20+X(3,30)\times 20)/70$$

$$X(2,28)'=(X(2,30)\times 12+X(3,30)\times 12+X(2,31)\times 23+X(3,31)\times 23)/70$$

$$X(2,29)'=(X(2,31)\times 9+X(3,31)\times 9+X(2,32)\times 26+X(3,32)\times 26)/70$$

-continued

$$X(2,30)'=(X(2,32)\times 6+X(3,32)\times 6+X(2,33)\times 29+X(3,33)\times 29)/70$$

$$X(2,31)'=(X(2,33)\times 3+X(3,33)\times 3+X(2,34)\times 32+X(3,34)\times 32)/70$$

Data for the two lines (third and fourth lines) of the extraction lines is calculated. This method would require a 1-line memory, as described below in detail.

FIG. **19** shows the concept for the lateral enlargement method in display mode **2** (640×480 dots). Here, enlargement of four pixels to five pixels is discussed.

In FIG. **19**, numeral **212** indicates 4-pixel display data and numeral **213** indicates 5-pixel display data after enlargement. The vertical axis is entered with 1 as the highest intensity and 0 as the lowest intensity and the horizontal axis is entered as pixel positions. To enlarge the 4-pixel data **212** to the 5-pixel data **213**, the 4-pixel width is divided into five equal parts, namely, the 1-pixel width is narrowed by one-fifth and display data of four-fifth pixel width is converted into display data of 1-pixel width. Therefore, the 1-pixel display data is expressed by

Expression6

$$X(0,0)'=(X(0,0)\times 4)/4$$

$$X(0,1)'=(X(0,0)\times 1+X(0,1)\times 3)/4$$

$$X(0,2)'=(X(0,1)\times 2+X(0,2)\times 2)/4$$

$$X(0,3)'=(X(0,2)\times 3+X(0,3)\times 1)/4$$

$$X(0,4)'=(X(0,3)\times 4)/4$$

where data to which "'" is attached is gray scale data after processing. In fact, to enlarge 640 pixels to 1024 pixels, five pixels are enlarged to eight pixels from 1024/640=8/5. This is expressed by

Expression7

$$X(0,0)'=(X(0,0)\times 5)/5$$

$$X(0,1)'=(X(0,0)\times 3+X(0,1)\times 2)/5$$

$$X(0,2)'=(X(0,1)\times 5)/5$$

$$X(0,3)'=(X(0,1)\times 1+X(0,2)\times 4)/5$$

$$X(0,4)'=(X(0,2)\times 4+X(0,3)\times 1)/5$$

$$X(0,5)'=(X(0,3)\times 5)/5$$

$$X(0,6)'=(X(0,3)\times 2+X(0,4)\times 3)/5$$

$$X(0,7)'=(X(0,4)\times 5)/5$$

Like the reduction process, to use a similar method for longitudinal processing, a memory for a plurality of lines would be required, which would increase the size of the circuit. Thus, the following processing can also be performed so as not to increase the circuit scale.

FIG. **20** shows enlargement by gray scale insertion wherein a longitudinal enlargement method is also shown. To enlarge 480 lines to 768 lines in the longitudinal direction, the insertion of 288 lines is required. In FIG. **20**, numerals **214** and **215** indicate extraction lines to represent the insertion position and numeral **216** indicates an insertion line after enlargement. Longitudinal enlargement is executed by inserting the insertion line **216** which is a gray scale for the extraction lines **214** and **215** between the extraction lines **214** and **215**. Therefore, the pixels, other than the insertion line **216**, to which "'" is attached are pixels enlarged using Expression 4 in the lateral direction, and to process the extraction lines **214** and **215** using Expression 4 and average these two lines, the insertion line **216** is

$$X(3,0)' = (X(2,0)\times 5 + X(3,0)\times 5)/10 \quad \text{Expression8}$$

$$X(3,1)' = (X(2,0)\times 3 + X(3,0)\times 3 + X(2,1)\times 2 + X(3,1)\times 2)/10$$

$$X(3,2)' = (X(2,1)\times 5 + X(3,1)\times 5)/10$$

$$X(3,3)' = (X(2,1)\times 1 + X(3,1)\times 1 + X(2,2)\times 4 + X(3,2)\times 4)/10$$

$$X(3,4)' = (X(2,2)\times 4 + X(3,2)\times 4 + X(2,3)\times 1 + X(3,3)\times 1)/10$$

$$X(3,5)' = (X(2,3)\times 5 + X(3,3)\times 5)/10$$

$$X(3,6)' = (X(2,3)\times 2 + X(3,3)\times 2 + X(2,4)\times 3 + X(3,4)\times 3)/10$$

$$X(3,7)' = (X(2,4)\times 5 + X(3,4)\times 5)/10$$

Data for two lines is calculated. The calculation is executed for each color, thereby converting the display data.

As described above, the calculation is executed separately for each of R, G, and B. At that time, fractional digits may occur. To clarify the difference between the background color and text and graphics colors, it is desirable to handle the fractional digits so that a color different from the background color is output in response to the attributes of the background color. For example, if the background is black (R=0000, G=0000, B=0000), when the average values of R, G, and B are calculated, fractions are rounded up or rounded off, and if the background is white (R=1111, G=1111, B=1111), fractions are rounded down, whereby a color different from the background color can be displayed. If the background color has different R, G, and B attributes such as blue (R=0000, G=0000, B=1111), fractions are rounded up when gradation of R or G is calculated, or fractions are rounded down when gradation of B is calculated.

The extraction line positions in longitudinal reduction or enlargement may be equally spaced as desired, or lines with less display data may be found and set to extraction lines.

Like FIG. **4**, FIG. **21** shows a method of determining the position of a horizontal or vertical extraction line where replacement or insertion is to be made from the display data amount, wherein only a horizontally extending area is detected. In FIG. **21**, numeral **217** indicates the summation result of the number of pixels displayed in a color different from the background color for each horizontal line and numeral **218** indicates positions of horizontal lines where insertion or deletion can be made, determined from the summation result **217**. In the example, positions having as little display data as possible are found for replacement or insertion positions. For a screen with windows displayed, an area outside the window regions may be detected for replacement or insertion positions.

Next, an example of the hardware configuration of the data conversion section **4** for carrying out the first operation example shown in FIG. **17** will be discussed.

FIG. **22** is a configuration example of the data conversion section **4**, wherein numerals **219**, **220**, and **221** indicate R display data, C display data, and B display data of display data **2** respectively, numeral **222** indicates an R data converter, numeral **223** indicates a G data converter, numeral **224** indicates a B data converter, numeral **225** indicates R liquid crystal display data, numeral **226** indicates G liquid crystal display data, numeral **227** indicates B liquid crystal display data, numeral **81** is a display position determination section, numeral **82** is a lateral display position signal, numeral **83** is a longitudinal display position signal, numeral **228** indicates a display mode determination section, numeral **229** indicates a display mode signal, and numeral **230** indicates a liquid crystal display timing signal generator. The display position determination section **81** determines the display position of each pixel of the display data **2** from a timing signal **3** and outputs the lateral position as the lateral display position signal **82** and the longitudinal position as the longitudinal display position signal **83**. The display mode determination section **228** determines the display mode from the timing signal **3** and outputs the display mode signal **229**. The data converters **222**, **223**, and **224** process the R, G, and B display data **219**, **220**, and **221** respectively in accordance with the resolution represented by the display mode signal **229** and the display position indicated by the lateral and longitudinal display position signals **82** and **83**. The liquid crystal display timing signal generator **230** generates a liquid crystal display timing signal **6** matched with the output resolution represented by the display mode signal **229** from the timing signal **3**.

FIG. **23** is an example of the configuration of the R data converter **222**. The G and B data converters **223** and **224** also each have the same configuration as the R data converter **24**.

In FIG. **23**, numeral **231** indicates a reduction process section, numeral **232** indicates an enlargement process section, numeral **233** indicates reduced display data, numeral **234** indicates enlarged display data, and numeral **235** indicates a resolution switch means. When the display mode signal **229** represents the display mode **1**, the reduction process section **231** converts the R display data **219** into the reduced display data **233** in response to the lateral display position signal **82** and longitudinal display position signal **83**; at that time, the enlargement process section **232** does not operate. When the display mode signal **229** represents the display mode **2**, the enlargement process section **232** converts the R display data **219** into the enlarged display data **234** in response to the lateral display position signal **82** and longitudinal display position signal **83**; at that time, the reduction process section **231** does not operate. The resolution switch means **235** is responsive to the display mode signal **229** for outputting the reduced display signal **233** when the signal **229** represents the display mode **1** or the enlarged display signal **234** when the signal **229** represents the display mode **2** as the R liquid crystal display signal **225**. Although the reduction process section **231** and the enlargement process section **232** are provided to support two display modes in the embodiment, additional reduction or enlargement process sections can also be provided for supporting other resolutions.

FIG. **24** is one example of the configuration of the reduction process section **231**. As described above, a horizontal row of pixels of display data is referred to as a line. This means that the liquid crystal panel **7** used in the invention consists of 1024 pixels×768 lines and that the display mode **1** provides 1120 pixels×780 lines.

In FIG. **24**, numeral **236** indicates a pre-preceding dot data latch, numeral **237** indicates a preceding dot data latch, numeral **238** indicates pre-preceding dot data, numeral **239** indicates preceding dot data, numeral **240** indicates a lateral operation section, numeral **241** indicates laterally reduced data, numeral **242** indicates a line memory, numeral **243** indicates preceding line data, numeral **244** indicates a longitudinal operation section, numeral **245** indicates longitudinal gray scale data and numeral **246** indicates an output selector. The preceding dot data latch **237**, which latches the R display data **219** in response to a dot clock, outputs the preceding dot data **239** which is display data one pixel before the R display data **219**. The pre-preceding dot data latch **236**, which latches the preceding dot data **239** in response to a dot clock, outputs the pre-preceding dot data **238** which is display data two pixels before the R display data **219**. The lateral operation section **240** performs an operation on the R display data **219** and the preceding dot data **239**, the pre-preceding dot data **238** according to Expression 4 in response to the lateral display position signal **82** depending on which pixel position of the liquid crystal panel **7** the R display data **219** is at, and outputs the result as the laterally reduced data **241**, as described below in detail. The line memory **242** stores one line of the laterally reduced data **241** and outputs as the preceding line data **243** which is data one line before when the R display data **219** of the next line is input. The longitudinal operation section **244** performs an operation on the laterally reduced data **241** and the preceding line data **243** in response to the longitudinal display position signal **83** depending on which line position of the liquid crystal panel **7** the R display data **219** is at, and outputs the result as the longitudinal gray scale data **245**, as described below in detail. The output data selector **246** selects the laterally reduced data **241** or the longitudinal gray scale data **245** and outputs or does not output them in response to the longitudinal display position signal **83**, as described in detail below.

FIG. **25** is an example of the configuration of the enlargement process section **232**, wherein numeral **247** indicates laterally enlarged data, numeral **248** indicates a gray scale data frame memory, numeral **249** indicates a display data frame memory, numeral **250** indicates read insertion data, and numeral **251** indicates read display data. Other components identical with those of the reduction process section **231** previously described with reference to FIG. **24** are denoted by the same reference numerals in FIG. **25**.

In FIG. **25**, a preceding dot data latch **237** operates like that of the reduction process section **231**. The lateral operation section **240** performs an operation according to Expression **7** in response to the lateral display position signal **82** and outputs the result as the laterally enlarged data **247**. A line memory **242** and a longitudinal operation section **244** operate like those of the reduction process section **231**. The gray scale data frame memory **248** stores longitudinal gray scale data **245** for one frame and the display data frame memory **249** stores laterally enlarged data **247** for one frame. When display data of the next frame is input, the read insertion data **250** is read and inserted into any position between the read display data **251** in response to the longitudinal display position signal **83** for performing enlargement processes.

Next, the operation related to the reduction process according to the invention will be discussed in detail.

In FIG. **1**, the data conversion section **4** converts the display data **2** and the timing signal **3** into the liquid display data **5** and the liquid crystal display timing signal **6** matched with the liquid crystal panel **7** for output. In FIG. **22**, the display position determination section **81** determines the position at which display data is to be displayed from the timing signal **3** and generates the lateral display position signal **82** and the longitudinal display position signal **83**. The lateral display position can be determined by counting liquid crystal display clock pulses (dot clock pulses) of the timing signal **3** and the longitudinal display position can be determined by counting liquid crystal horizontal clock pulses (line clock pulses) of the timing signal **3**. The display mode determination section **228** determines the display mode from the timing signal **3** and the display mode signal **229** matched with the resolution of the liquid crystal panel **7** for display. To determine the display mode, the number of lateral (horizontal) dots can be determined by counting the number of liquid crystal display clocks in one period of the liquid crystal horizontal clock of the timing signal **3** and the number of longitudinal (vertical) lines can be determined by counting the number of liquid crystal horizontal synchronizing signal periods in one period of liquid crystal vertical synchronizing signal. The display mode signal **229** can also be fed from an external system without providing the display mode determination section **228**.

The R, G, and B for the display data **2** are input to the R, G, and B data converters **222**, **223**, and **224** respectively, which then convert the data into the liquid crystal display data **5** matched with the display mode represented by the display mode signal **229**. The liquid crystal display timing signal generator **230** generates the liquid crystal display timing signal **6** matched with the display mode represented by the display mode signal **229** from the timing signal **3**.

The operation of the R data converter **222** for display data conversion will be discussed in detail with reference to FIG. **23**. Each of the G and B data converters **223** and **224** performs similar operations to that of the R data converter **222**.

In FIG. **23**, when the display mode signal **229** represents the display mode **1**, the reduction process section **231** operates and generates the reduced display data **233** in response to the lateral display position signal **82** and the longitudinal display position signal **83**. When the display mode signal **229** represents the display mode **2**, the enlargement process section **232** operates and generates the enlarged display data **234** in response to the lateral display position signal **82** and the longitudinal display position signal **83**. The resolution switch means **235** is responsive to the display mode signal **229** for selecting and outputting the reduced display data **233** in the display mode I or the enlarged display data **234** in the display mode **2**. As described above, additional reduction and enlargement process sections can be provided to make up a data conversion section which supports every resolution.

The operation of the reduction process section **231** will be discussed in detail with reference to FIGS. **24**, **27**, and **28**. In FIG. **24**, the preceding dot data latch **237**, which latches R display data **219** according to a dot clock, outputs the preceding dot display data **239** which is the data one dot before the R data **219**. The pre-preceding dot data latch **236**, which latches the preceding dot data **239** according to a dot clock, outputs the pre-preceding dot data **238** which is the data two dots before the R data **219**. The lateral operation section **240** comprises an adder, multiplier, and divider. When the R display data **219** indicated by the lateral display position signal **82** is at the position X (0, 0)-X (0, 10), X (0, 13)-X (0, 23), or X (0, 26)-X (0, 34) shown in Expression 4, the lateral operation section **240** performs an operation on the R display data **219** and the preceding dot data **239**; when the R display data **219** is at the position X (0, 12) or X (0, 25), the lateral operation section **240** performs an operation on the R display data **219**, the preceding dot data **239**, and the pre-preceding dot data **238**; when the R display data **219** is at the position X (0, 11) or X (0, 24), the lateral operation section **240** does not output any data, thereby executing the operation shown in Expression 4. Lateral reduction can be accomplished by repeating similar calculations in 35-dot units. When the position of the R display data **219** indicated by the longitudinal display position signal **83** is the line next to the extraction line **210** shown in FIG. **18**, the longitudinal operation section **244** performs an operation on the laterally reduced data **241** and the preceding line data **243**; otherwise, the longitudinal operation section **244** does not operate. When the position of the R display data **219** indicated by the longitudinal display position signal **83** is the extraction line **210** shown in FIG. **18**, the output data selector **246** does not output display data; when the position is the line next to the extraction line **210** shown in FIG. **18**, the output data selector **246** outputs the longitudinal reduced data **245**; otherwise, it outputs the laterally reduced data **241**.

FIG. **27** is an input/output timing chart for the lateral reduction process for the reduction process section **231**.

In the figure, numeral **2102** indicates the input timing for the R display data **219**, numeral **2103** indicates the output timing of preceding dot data **239**, numeral **2104** indicates the output timing for the pre-preceding dot data **238**, numeral **2105** indicates the output timing for the synchronous clock contained in the liquid crystal display timing signal **6**, numeral **2106** indicates the output timing of laterally reduced data **241**, and numeral **2107** indicates hatched data on which a lateral operation is to be performed. Each number following X represents the lateral display position (dot position) 0 to 34. Each number to which "'" is suffixed, shown in the output timing **2104** of the laterally reduced data **241** represents the display position after lateral reduction. For example, the first dot **X0'** of the laterally reduced data **241** is the result of performing an operation on **X0** and **X1** shown as hatched data **2107**, and **X10'** is the result of performing an operation on **X10**, **X11**, and **X12**. The operation is performed according to Expression 4 in response to the lateral display position signal **82**. The clock at the positions of **X1**, **X13**, and **X25** of R display data is stopped and laterally reduced data **241** is output in synchronization with it, thereby deleting 3-dot data.

FIG. **28** is an input/output timing chart for the longitudinal reduction process for the reduction process section **231**.

In the figure, numeral **2108** indicates the line output timing for the laterally reduced data, numeral **2109** indicates the output timing of the preceding line signal **243** output by the line memory **242**, numeral **2110** indicates the output timing of longitudinal gray scale data **245** generated by performing an operation on the output of the line memory and the laterally reduced data, and numeral **2112** indicates the output timing of the reduced display data **233** output from the output data selector **246**. **L0** and **L1** denote data for the first line and data for the second line respectively; **L0** and **L1** are averaged to generate the longitudinal reduced data. This also applies to the second line, third line, and later. Numeral **2111** indicates a longitudinal position signal, which becomes a selection signal for the output data selector **246** to allow the longitudinal reduced data **245** to be output on the line next to the extraction line **210** shown in FIG. **18**. Numeral **2112** indicates the output timing for the reduced display data **233**, numeral **2113** indicates the output timing for a horizontal synchronizing signal contained in the liquid crystal display timing signal **6**, and numeral **2114** indicates the timing of display data actually displayed. Although the output timing **2112** for the output data selector **246** follows the longitudinal position signal timing **2111**, **L1** is not displayed as shown in **2114** because the actual horizontal synchronizing signal is as shown in **2113**.

The enlargement process according to the invention will be discussed in detail with reference to FIGS. **25**, **12**, and **29**.

In FIG. **25**, the preceding dot data latch **237** operates like that for the reduction process section **53**. When R display data **219** indicated by the lateral display position signal **82** is data at the dot position X (0, 0) shown in Expression 6, the lateral operation section **240** performs an operation only on the R display data **219**; when the R display data **219** is data at the dot position X (0, 1), X (0, 3), or X (0, 4), the lateral operation section **240** outputs 2-dot data for the operation result on the R display data **219** and the preceding dot data **239** and the operation result on only the R display data **219** while 1-dot R display data **219** is input; when the R display data **219** is data at the dot position X (0, 2), the lateral operation section **240** performs an operation on the R display data **219** and the preceding dot data **239**.

In FIG. **25**, the line memory **242** and the longitudinal operation section **244** operate like those of the reduction process section **231**. Longitudinal gray scale data **245** for one screen (frame) is stored in the gray scale data frame memory **248** and laterally enlarged data **247** for one screen (frame) is stored in the display data frame memory **249**. When display data for the next screen (frame) is input, the read insertion data **250** is read and inserted into any position between the read display data **251** in response to the longitudinal display position signal for inserting a horizontal line. When a number of insertion lines are equally spaced, for example, when a gray scale data line is inserted every n lines, (n+1) line memories are provided for storing inserted gray scale data and line data. When the next data is input, the (n+1)-line data containing the gray scale line data is read out while n-line data is stored, whereby a horizontal line can be inserted without providing the frame memories.

FIG. **26** is an input/output timing chart for the lateral enlargement process of the enlargement process section **232**.

In the figure, numeral **2115** indicates the input timing of R display data **219**, numeral **2116** indicates the output timing of preceding dot data **239**, and numeral **2117** indicates the output timing of a synchronous clock contained in the liquid crystal display timing signal **6**, and numeral **2118** indicates the output timing of lateral enlarged data **247**. Each digit following X represents the lateral display position (dot position) 0 to 4. **X0'** to **X7'** of the laterally enlarged data **247** are the operation results according to Expression 7; while 5-dot data is input, 8-dot data is output according to the synchronous clock timing **2117**.

FIG. **29** is an input/output timing chart for the longitudinal enlargement process of the enlargement process section **232**.

In the figure, numeral **2119** indicates the output timing of laterally enlarged data **247** for each line, numeral **2120** indicates the output timing of the preceding line data **243** for each line, output from the line memory **242**, and numeral **2121** indicates the output timing of longitudinal gray scale data **245** for each line, showing that the longitudinal gray scale data **245** is the result of dividing by two the sum of the laterally enlarged data **247** and the preceding line data **243** which is the data one line before the lateral enlarged data **247**. Numeral **2122** indicates the input timing of the longitudinal display position signal **83**, numeral **2123** indicates a horizontal synchronizing signal contained in the liquid crystal display timing signal **6**, and numeral **2124** indicates the timing for each line displayed on the liquid crystal panel **7**. The longitudinal display position signal input timing **2122** is set to "1" on the line next to the extraction line **214** shown in FIG. **20**. At this time, the period of the synchronous clock is doubled and while 1-line data is input, 2-line data is output. For the first one of these two lines, the longitudinal gray scale data is selectively output from the gray scale data frame memory **248** and for the second line, the laterally enlarged data is selectively output from the display data frame memory **249** by the output selector **246**.

Next, a system which simplifies the operation section will be discussed as another example of the data conversion section **4** according to another embodiment of the invention.

To simplify the operation expressions given in the first example of the data conversion section **4**; the dividers may be omitted by assigning 8 or 16 to each divisor. Therefore, the operation section can be simplified by reducing 16 pixels to 15 pixels according to Expression 9 or eight pixels to seven pixels according to Expression 10:

$$X(0,0)'=(X(0,0)\times 15+X(0,1)\times 1)/16 \quad \text{Expression9}$$
$$X(0,1)'=(X(0,1)\times 14+X(0,2)\times 2)/16$$
$$X(0,2)'=(X(0,2)\times 13+X(0,3)\times 3)/16$$
$$X(0,3)'=(X(0,3)\times 12+X(0,4)\times 4)/16$$
$$X(0,4)'=(X(0,4)\times 11+X(0,5)\times 5)/16$$
$$X(0,5)'=(X(0,5)\times 10+X(0,6)\times 6)/16$$
$$X(0,6)'=(X(0,6)\times 9+X(0,7)\times 7)/16$$
$$X(0,7)'=(X(0,7)\times 8+X(0,8)\times 8)/16$$
$$X(0,8)'=(X(0,8)\times 7+X(0,9)\times 9)/16$$
$$X(0,9)'=(X(0,9)\times 6+X(0,10)\times 10)/16$$
$$X(0,10)'=(X(0,10)\times 5+X(0,11)\times 11)/16$$
$$X(0,11)'=(X(0,11)\times 4+X(0,12)\times 12)/16$$
$$X(0,12)'=(X(0,12)\times 3+X(0,13)\times 13)/16$$
$$X(0,13)'=(X(0,13)\times 2+X(0,14)\times 14)/16$$
$$X(0,14)'=(X(0,14)\times 1+X(0,15)\times 15)/16$$

$$X(0,0)'=(X(0,0)\times 7+X(0,1)\times 1)/8 \quad \text{Expression10}$$
$$X(0,1)'=(X(0,1)\times 6+X(0,2)\times 2)/8$$
$$X(0,2)'=(X(0,2)\times 5+X(0,3)\times 3)/8$$
$$X(0,3)'=(X(0,3)\times 4+X(0,5)\times 5)/8$$
$$X(0,4)'=(X(0,4)\times 3+X(0,1)\times 1)/8$$
$$X(0,5)'=(X(0,5)\times 2+X(0,6)\times 6)/8$$
$$X(0,6)'=(X(0,6)\times 1+X(0,7)\times 7)/8$$

These expressions can be used to reduce 1120 lateral pixels to 1024 pixels by reducing from 16 pixels to 15 pixels for 704 pixels of the 1120 pixels and from eight pixels to seven pixels for 416 pixels. Thus, reduction process compatible with every resolution can be carried out by combining reduction methods by which dividers can be omitted.

As still another example of the data conversion section **4**, a system which executes reduction process in dot units will be discussed with reference to FIG. **30**. Here, assume that a dot refers to a display element of each of R, G, and B making up one pixel of a color liquid crystal panel and that one pixel consists of three dots. The pixels of R, G, and B are arranged in order on a horizontal line on the liquid crystal panel.

FIG. **30** shows a concept of reduction process executed in dot units. Here, assume that 12 pixels are to be reduced to 11 pixels, namely, 36 dots to 33 dots.

In FIG. **30**, numerals **254**, **255**, and **256** indicate first, second, and third extraction pixels respectively. Gray scale (average) of the display data in the B dot of the first extraction pixel **254** and the display data in the B dot of its preceding pixel is calculated and the result is displayed in the B dot of the pixel preceding the first extraction pixel **254**. Gray scale (average) of the display data in the G dot of the second extraction pixel **255** and the display data in the G dot of its preceding pixel is calculated and the result is displayed in the G dot of the pixel preceding the second extraction pixel **255**. Gray scale (average) of the display data in the R dot of the third extraction pixel **256** and the display data in the R dot of its preceding pixel is calculated and the result is displayed in the R dot of the pixel preceding the third extraction pixel **256**. Since the system performs reduction process in units of dots smaller than pixels, characters and graphics are less deformed. Alternatively, six pixels can also be reduced to five pixels, namely, 18 dots to 15 dots.

The data conversion section **4** which performs the processing may be software using the CPU **101**, may be made of hardware, may exist in the PC **1**, or may be contained in the liquid crystal panel **7**.

An example of a system to which the invention is applied will be discussed with reference to FIGS. **31** and **32**.

FIG. **31** is a conceptual illustration of the system to which the invention is applied.

In FIG. **31**, numeral **257** indicates a workstation or personal computer which contains a central processing unit and a numeral **258** indicates a liquid crystal display unit. The workstation or personal computer **257** outputs display data having different resolutions and the liquid crystal display unit **258** has means for converting the input display data in accordance with the resolution of its own liquid crystal panel. Here, assume that the workstation or personal computer **257** outputs display data having three resolutions of 1120×780 dots, 1024×768 dots, and 640×480 dots and that the liquid crystal display unit **257** has a liquid crystal panel of a resolution of 1024×768 dots.

FIG. **32** shows the configuration of the liquid crystal display unit **258**, wherein numeral **259** indicates PC display data, numeral **260** indicates a PC vertical synchronizing signal, numeral **261** indicates a PC horizontal synchronizing signal, and numeral **262** indicates an input circuit. The input circuit **262** converts an input signal into a TTL level. For example, if the input signal is at ECL level, the input circuit **262** converts the ECL level into TTL level; if the input signal is an analog signal, the input circuit **262** converts the analog signal into digital form; if the input signal is at TTL level, the input circuit **262** serves as a buffer. Numeral **263** indicates a clock generator which generates a liquid crystal display clock, one of liquid crystal timing signals synchronized with the PC display data **259** from the PC horizontal synchronizing signal **261**. Numeral **4** indicates a data conversion section which operates as the data conversion section **4** described above, and here determines the resolution of the PC display data **259** from the liquid crystal timing signal **3** and executes reduction process when the resolution is 1120×780 dots, outputs the PC display data as it is when the resolution is 1024×768 dots, or executes enlargement process when 640×480 dots.

We have discussed the enlargement/reduction techniques as execution of the enlargement or reduction process so that the display data output from the PC **1** is made the same as the liquid crystal panel in resolution directly, but a technique of step-by-step execution of enlargement or reduction process may be used as described above.

Thus, display data can be displayed on a panel having a different resolution by enlarging or reducing the display data using algorithms of generating 32-pixel data from 35-pixel data, 15-pixel data from 16-pixel data, 7-pixel data from 8-pixel data, 8-pixel data from 5-pixel data, etc.

As described above, operations are performed on gradation information on a plurality of pixels or dots and display data is enlarged or reduced according to the result, whereby even display data output by the personal computer system assuming an output device having resolution different from that of the liquid crystal display can be displayed without erasing thin lines or deforming characters and without impairing display information of the resolution before enlargement or reduction. That is, a liquid crystal display system which enables multi-scanning display can be provided.

Considering the current state in which a large number of software products are already distributed, the system can eliminate the need for correcting a large number of software products so as to output signals matched with the resolution of a liquid crystal display from a computer to enable multi-scanning; an inexpensive system can be provided.

What is claimed is:

1. A method of converting first display data for a liquid crystal display having a first horizontal resolution received from an external system into second display data for a liquid crystal display having a second horizontal resolution smaller than the first horizontal resolution, said method comprising the steps of:

a) generating N dots based on a set of M contiguous dots on a horizontal line of the first display data, where M is an integer of three or greater and N is an integer of two or more being less than M;

b) replacing the set of M contiguous dots on the horizontal line of the first display data with the N dots;

c) repeating steps a) to b) for different sets of M contiguous dots on the horizontal line of the first display data in sequence at least in a part of the horizontal line of the first display data; and

d) repeating step c) for different horizontal lines of the first display data in sequence;

wherein the step a) generates the N dots based on the set of M contiguous dots on the horizontal line of the first display data such that the set of M contiguous dots is virtually divided into N equal partitions, and as to each of the N equal partitions a new dot is generated by averaging one or more dots contained in the partition concerned; and

wherein when a dot of the M contiguous dots is located on a border between two partitions, the dot is assigned to each of the two partitions to be added with a weight according to a percentage of an area of the dot in each of the two partitions.

2. The method as claimed in claim **1**, wherein M is 35 and N is 32.

3. The method as claimed in claim **1**, wherein M is 16 and N is 15.

4. The method as claimed in claim **1**, wherein M is eight and N is seven.

5. The method as claimed in claim **1** wherein each horizontal line of the first display data is divided into at least first and second horizontal line portions and a ratio of M and N is set different between in the first horizontal line portion and in the second horizontal line portion.

6. The method as claimed in claim **5**, wherein M and N are set equal to eight and seven for the first horizontal line portion, respectively, and M and N are set equal to sixteen and fifteen for the second horizontal line portion, respectively.

7. The method as claimed in claim **1**, further comprising the steps of:

e) generating data for n horizontal lines based on specific m horizontal lines contiguous to each other of the first display data, where m is an integer of two or greater and n is an integer less than m;

f) repeating at least one of the following steps g) and h) as many times as required in sequence at different positions on a screen of the liquid crystal display;

g) replacing k ($n<k\leqq m$) lines of the m horizontal lines with the n horizontal lines; and

h) adding the n horizontal lines to the m horizontal lines;

whereby the first data having the first vertical resolution is converted into the display data having the second vertical resolution which differs from the first vertical resolution.

8. The method as claimed in claim **7**, wherein m is two, n is one, and k is two.

9. The method as claimed in claim **7**, wherein m is three, n is one, and k is two.

10. The method as claimed in claim **1**, wherein the first display data has a first vertical resolution and the second display data has a second vertical resolution different from the first vertical resolution; and

wherein the method further comprises the steps of:

e) generating Q dots based on a set of P contiguous dots on a vertical line of the first display data, where P is an integer of three or greater and Q is an integer of two or more being less than P;

f) replacing the set of P contiguous dots on the vertical line with the Q dots;

g repeating steps e) to f) for different sets of P contiguous dots on the vertical line of the first display data in sequence at least in a part of the vertical line of the first display data; and

h) repeating step g for different vertical lines of the first display data in sequence;

wherein the step e) generates the Q dots based on the set of P contiguous dots on the vertical line of the first display data such that the set of P contiguous dots is virtually divided into Q equal partitions, and as to each of the Q equal partitions, a new dot is generated by averaging one or more dots contained in the partition concerned; and

wherein when a dot of the P contiguous dots is located on a border between two partitions, the dot is assigned to each of the two partitions to be added with a weight according to a percentage of an area of the dot in each of the two partitions;

whereby the first display data having the first vertical resolution is converted into the display data having the second vertical resolution different from the first vertical resolution.

11. The method as claimed in claim **10**, wherein the sets of P contiguous dots are selected out of a screen area which contains substantially only background color dots of the first display data.

12. The method as claimed in claim **1**, wherein the sets of M contiguous dots are selected out of a screen area which contains substantially only background color dots of the first display data.

13. The method as claimed in claim **1**, wherein each horizontal line of the first display data is divided into first, second, and third horizontal line portions, and step d) is applied only to the second horizontal line portion without being applied to the first and third horizontal line portions.

14. A method of converting first display data for a liquid crystal display having a first horizontal resolution received from an external system into second display data for a liquid crystal display having a second horizontal resolution larger than the first horizontal resolution, said method comprising the steps of:

a) generating N dots based on a set of m contiguous dots on a horizontal line of the first display data, where M is an integer of two or greater and N is an integer of three or more being greater than M;

b) replacing the set of M contiguous dots on the horizontal line of the first display data with the N dots;

c) repeating steps a) to b) for different sets M contiguous dots on the horizontal line of the first display data in sequence at least in a part of the horizontal line of the first display data; and

d) repeating step c) for different horizontal lines of the first display data in sequence;

wherein the step a) generates the N dots based on the set of M contiguous dots on the horizontal line of the first display data such that the set of M contiguous dots is virtually divided into N equal partitions, and as to each of the N equal partitions, a new dot is generated by averaging one or more dots contained in the partition concerned; and

wherein when a dot of the M contiguous dots is located on a border between two partitions, the dot is assigned to each of the two partitions to be added with a weight according to a percentage of an area of the dot in each of the two partitions.

15. The method as claimed in claim **14** wherein M is five and N is eight.

16. The method as claimed in claim **14**, further comprising the steps of:

e) generating data for n horizontal lines based on specific m horizontal lines contiguous to each other of the first display data, where m is an integer of two or greater and n is an integer less than m;

f) repeating at least one of the following steps h) and i) as many times as required in sequence at different positions on a screen of the liquid crystal display;

g) replacing k ($n<k\leqq m$) lines of the m horizontal lines with the n horizontal lines; and

h) adding the n horizontal lines to the m horizontal lines;

whereby the first data having the first vertical resolution is converted into the display data having the second vertical resolution which differs from the first vertical resolution.

17. The method as claimed in claim **16**, wherein m is two, n is one, and k is two.

18. The method as claimed in claim **16**, wherein m is three, n is one, and k is two.

19. A method of converting first color display data in a raster scan format having a first horizontal resolution received from an external system into second color display data for a liquid crystal display having a second horizontal resolution smaller than the first horizontal resolution, the liquid crystal display including pixels each consisting of three primary color dots of R (red), G (green), and B (blue), said method comprising the steps of:

a) averaging data values of both a different primary color dot of each of three pixels which are at least every other pixel of M contiguous pixels on each horizontal line of the first display data and the same color dot of a pixel immediately preceding the pixels, where M is an integer of six or greater;

b) sharing the average values as data values of the different primary color dots between the three pixels which are at least every other pixel of M contiguous pixels and their respective immediately preceding pixels;

c) for data for M−1 pixels thus obtained from the first display data, changing an arrangement of the primary color dots of the data so that it matches an arrangement of primary color dots of the liquid crystal display;

d) assigning data for each primary color dot of the M−1 pixels whose primary color dot arrangement is changed to each primary color dot of M−1 contiguous pixels of the liquid crystal display; and

e) repeating steps a) to d) for different sets of M pixels on each horizontal line in sequence.

20. The method as claimed in claim **19**, wherein M is 12.

21. A method of converting first display data for a liquid crystal display having a first horizontal resolution received from an external system into second display data for a liquid crystal display having a second horizontal resolution larger than the first horizontal resolution, the method comprising the steps of:

a) generating N dots based on a set of M contiguous dots on a horizontal line of the first display data, where M is an integer of two or greater, N is an integer of three or more being greater than M, and $(N-M)/(M-1)$ is not an integer;

b) replacing the set of M contiguous dots on the horizontal line of the first display data with the N dots;

c) repeating steps a) to b) for different sets of contiguous dots on the horizontal line of the first display data in sequence at least in a part of the horizontal line of the first display data; and

d) repeating step c) for different horizontal lines of the first display data in sequence;

wherein the step a) generates the N dots based on the set of M contiguous dots on the horizontal line of the first display data such that the set of M contiguous dots is virtually divided into N equal partitions, and as to each of the N equal partitions, a new dot is generated by averaging one or more dots contained in the partition concerned; and

wherein when a dot of the M contiguous dots is located on a border between two partitions, the dot is assigned to each of the two partitions to be added with a weight according to a percentage of an area of the dot in each of the two partitions.

22. The method as claimed in claim **21**, wherein M is five and N is eight.

23. The method as claimed in claim **21**, wherein the first display data has a first vertical resolution and the second display data has a second vertical resolution different from the first vertical resolution; and

wherein the method further comprises the steps of:

e) generating Q dots based on a set of P contiguous dots on a vertical line of the first display data into Q equal partitions, where P is an integer of two or greater and Q is an integer of three or more being greater than P;

f) replacing the set of P contiguous dots on the vertical line of the first display data with the Q dots;

g) repeating steps e) to f) for different sets of P contiguous dots on the vertical line of the first display data in sequence at least in a part of the vertical line of the first display data; and

h) repeating step g) for different vertical lines of the first display data in sequence;

wherein the step e) generates the Q dots based on the set of P contiguous dots on the vertical line of the first display data such that the set of P contiguous dots is virtually divided into Q equal partitions, and as to each of the Q equal partitions, a new dot is generated by averaging one or more dots contained in the partition concerned; and

wherein when a dot of the P contiguous dots is located on a border between two partitions, the dot is assigned to each of the two partitions to be added with a weight according to a percentage of an area of the dot in each of the two partitions;

whereby the first display data having the first vertical resolution is converted into the second display data having the second vertical resolution different from the first vertical resolution.

24. The method as claimed in claim **23**, wherein P is four and Q is five.

25. The method as claimed in claim **23**, wherein the sets of P contiguous dots are selected out of a screen area which contains substantially only background color dots of the first display data.

26. The method as claimed in claim **21**, wherein M is four and N is five.

27. The method as claimed in claim **21**, wherein the sets of M contiguous dots are selected out of a screen area which contain substantially only background color dots of the first display data.

28. A circuit for converting first display data in a raster scan format having a first resolution and a first timing signal received from an external system into second display data for a liquid crystal display having a second resolution different from the first resolution and a second timing signal, the circuit comprising:

a latch which outputs the first display data after a delay to produce delayed first display data;

a horizontal calculation unit which performs a calculation based on the first display data and the delayed first display data;

a selector which selectively outputs one of the first display data and a calculation result obtained by the horizontal calculation unit depending on a position of the liquid crystal display to which the first display data corresponds; and

a circuit which generates the second timing signal based on the first timing signal.

29. A circuit for converting first display data in a raster scan format having a first resolution and a first timing signal received from an external system into second display data for a liquid crystal display having a second resolution different from the first resolution and a second timing signal, the circuit comprising:

a line memory which outputs the first display data after a delay of one line period to produce delayed first display data;

a vertical calculation unit which performs a calculation based on the first display data and the delayed first display data;

a selector which selectively outputs one of the first display data and a calculation result obtained by the vertical calculation unit depending on a position of the liquid crystal display to which the first display data corresponds; and

a circuit which generates the second timing signal based on the first timing signal.

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